COMMUTING IN A NEW CENTURY

The New Program for Mass Transportation

Appendices

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Executive Office of Transportation and Construction,
Commonwealth of Massachusetts

In cooperation with the
Massachusetts Bay Transportation Authority

In consultation with the
Executive Office of Communities and Development
Massachusetts Bay Transportation Authority Advisory Board
Massachusetts Highway Department
Metropolitan Area Planning Council

With the assistance of the
Central Transportation Planning Staff

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Appendix A
Glossary

Accessibility - Ability to reach a destination or use a facility or service without being impeded by physical, economic, or other barriers due to auditory, visual, mobility, and cognitive disabilities.

ADA (Americans with Disabilities Act) - Federal legislation prohibiting discrimination on the basis of disability, requiring accessible transportation services. See **Paratransit**.

Advisory Board (to the MBTA) - Group of representatives of 78 cities and towns served by the MBTA. Powers relate to MBTA budget review and appointment of MBTA board members and general manager.

Auto Reduction - The reduction in the number of automobile trips that occurs as a result of the new/upgraded service or facility. This is the difference between the amount of traffic projected for 2020 with and without the service, and is based on an auto occupancy rate of 1.29 passengers per vehicle.

CAAA (Clean Air Act Amendments of 1990) - Federal legislation that sets allowable levels, which are known as NAAQS, for various pollutants. Where these standards are not attained, officials must take specified actions within a set time frame or face sanctions, such as loss of federal highway funds.

CARAVAN for Commuters, Inc. - A public, non-profit organization that promotes ridesharing and assists in establishing transportation management associations.

CA/T - Central Artery/Third Harbor Tunnel project for the reconfiguration of Interstates 90 and 93.

CO (Carbon monoxide) - A colorless, tasteless gas produced primarily by inefficient combustion of organic fuels in transportation and industrial activities. Overly high levels of CO reduces oxygen in the bloodstream, preventing normal respiration. CO emissions are regulated by the CAAA.

Commuter rail - Generally applies to multi-car, high-speed rail transport utilizing exclusive frequently at-grade, rights-of-way with service between urban areas or between outlying suburbs and the urban core. Usually involves greater distances and fewer stops than those normally found with light and heavy rail transit within urban areas.

Core - For the purposes of the PMT, defined as the Boston and Cambridge.

Crosstown service - Non-radial transit service that does not enter the central business district (CBD).

Discretionary funds - Funds whose distribution is not automatic and not by formula but depends on the decision of some agency or party.

EIS (Environmental Impact Statement) - Document that studies all likely impacts that will result from major federally assisted programs. Impacts include those on the natural environment, as well as impacts on the economy, society, and built environment of historical and aesthetic significance.

EOTC (Executive Office of Transportation and Construction) - A cabinet-level agency that sets state policies and plans for all modes of transport and that oversees public transit services, general aviation programs, and the state and local highway network. Established under M.G.L. Chapters 6A and 161A.

EPA - United States Environmental Protection Agency.

Feeder service - Local transport providing passengers with connections to a longer, line-haul service.

FHWA - Federal Highway Administration.

Flexible funds - ISTEA funding categories that may be used for highway and/or transit programs.

Formula grants - Funds distributed according to some legislated or regulated scheme.

FRA - Federal Railroad Administration.

FTA - Federal Transit Administration.

Heavy rail (transit) - Generally applies to higher-speed, multi-car rail transport utilizing exclusive, grade-separated rights-of-way in subway tunnels, on the surface, or on aerial (elevated) structures. The Red Line is a heavy rail transit facility. See **LRT (light rail transit).**

HOV (high occupancy vehicle) - Applied to vehicles carrying two or more people. Roads may have lanes uniquely for HOV use, such as carpools, vanpools, and other ridesharing modes, and buses.

Intermodal - Planning that reflects a focus on connectivity between modes as a means of facilitating linked tripmaking. It emphasizes connections, choices, coordination and cooperation. (Source: US DOT Statewide Transportation Planning; Proposed Rules, March 2, 1993.)

ISTEA (Intermodal Surface Transportation Efficiency Act of 1991) - Federal legislation that restructures and authorizes increased funding levels for transit and highway programs and mandates a necessary role for MPOs in ISTEA planning and funding decisions, requiring comprehensive, regional transportation plans to the year 2015.

Key Station Plan - A document designating critical transit facilities needed to expand accessibility for individuals with disabilities and to meet the ADA requirements.

Land use - The purpose for which land or the structures on the land are being utilized: for example, commercial, residential, retail. Also used as a description of activities found throughout an urban area.

Line-haul service - Transport along a single corridor without branches.

Local service - Transit service involving many stops and low operating speeds with the purpose of picking up or delivering passengers as closely as possible to origins and destinations.

LRT (light rail transit) - Generally applies to single- or double-car, rail transport that uses mostly mixed, but not usually grade-separated, rights-of-way. LRT is an intermediate-capacity, intermediate speed mode with service capabilities between heavy rail transit and local bus. The Green Line is a LRT facility. See **heavy rail (transit)**.

Management System - As required by Section 303 of ISTEA, states (in coordination with metropolitan areas) must develop and begin implementing by October 1, 1994, management systems in six areas: congestion, intermodal, public transportation, pavement, bridges, and safety. The purpose of these systems is to provide information needed to make effective decisions on the use of limited resources to improve the efficiency of, and protect the investment in, the nation's existing and future infrastructure at all levels of jurisdictional control.

MAPC (Metropolitan Area Planning Council) - Regional comprehensive planning agency for the Boston Metropolitan Area, covering 101 communities. Comprised of officials from cities and towns, state agencies, and independent gubernatorial appointees. Established under M.G.L. Chapter 40B, § 24.

Massport (Massachusetts Port Authority) - Agency charged to operate and develop major commercial maritime and aviation facilities and the Tobin Bridge. Created as an independent authority in M.G.L. Chapter S73, § 2.

MBTA (Massachusetts Bay Transportation Authority) - Authority that provides mass transit service in Eastern Massachusetts. Established under M.G.L. Chapter 161A.

MHD (Massachusetts Highway Department) - Agency responsible for the design, construction, and maintenance of state highways and bridges. Established under M.G.L. Chapter 16, § 2.

Mode - A particular means of transportation (e.g., rail, automotive, bicycle, walk).

MPO (Metropolitan Planning Organization) - Specified by ISTEA as the organization responsible for comprehensive transportation planning and programming for urbanized areas.

Multimodal - Planning that reflects consideration of more than one mode to serve transportation needs in a given area and is included in the meaning of intermodal. (Source: US DOT Statewide Transportation Planning; Proposed Rules, March 2, 1993.)

NAAQS (National Ambient Air Quality Standards) - Federal standards that set allowable concentrations and exposure limits for ozone, CO, and PM_{10}.

Net Operating Cost - The total net operating cost which is operating cost minus fare revenue (in 1991 dollars).

New Transit Trips - The number of total new weekday transit trips on the new/upgraded service or facility for the year 2020. This figure includes only riders diverted from auto trips. It does not include any riders that may be diverted from other transit modes.

Nonattainment Area - A geographic region that the U.S. EPA has designated as not meeting the NAAQS. The Boston area has been designated serious nonattainment for ozone and moderate nonattainment for CO. See **NAAQS.**

NOx (nitrogen oxides) - Precursor emission that forms from high-temperature combustion processes. React with VOCs in the presence of heat and sunlight to form ozone.

Operating Costs - The cost to operate and maintain the new service. These costs given in the PMT are in 1991 dollars and are based on actual FY 1991 MBTA operating costs.

Ozone - A colorless gas with a sweet odor that is not a direct emission from transportation sources, but is formed when VOCs and NOx from car exhausts and certain industrial emissions combine in the presence of sunlight. Ground-level ozone is associated with smog conditions and initiates damage to lungs, trees, crops, and materials. Regulated by the CAAA.

Paratransit - A demand-responsive system that applies to a variety of smaller, flexibly-scheduled and routed transportation services using low capacity vehicles. Used by persons, such as the elderly and other persons with disabilities, for whom use of standard mass transit services may prove difficult.

Reduction in Regional Emissions - The percentage reduction in VOC in the 164 cities and towns in eastern Massachusetts represented in the CTPS Regional Model.

SAR (Strategic Assessment Report) - A report initiated by the Massachusetts Aeronautics Commission to reassess the long-term needs for high-speed intercity transport demand to and from the Boston region.

SIP (State Implementation Plan) - A document that contains procedures to comply with the NAAQS, as specified in the CAAA. Prepared by states and submitted to the U.S. EPA for approval.

SOV - Single Occupant Vehicle.

STIP - State Transportation Improvement Program. See **TIP.**

TDDs (Telecommunications Display Devices) - Apparatus that converts telephoned information to visual form on a computer screen. Useful to hearing or speech impaired individuals.

"3C" Process - A *continuing, comprehensive* transportation planning process carried out *cooperatively* by states and local communities.

Total Capital Costs - The cost to construct the new facility or service, including vehicle costs. The cost estimates are in 1991 dollars. The sources for the capital costs are based on estimates from MBTA consultant studies, estimates from the MBTA, or generated by CTPS using standard transit construction cost figures.

Total New Trips - Total new trips attracted to the new/upgraded service or facility for the year 2020. This includes both riders diverted from the auto mode and riders diverted from other transit modes. Total new trips is equal to the total number of new passenger boardings on the service, regardless of the direction of travel.

Transit (mass or public) - Generally refers to urban passenger transportation service, local in scope, provided to the public along established routes with fixed or variable schedules at published fares.

TCM (Transportation Control Measure) - Actions, which are usually found in a SIP, that improve traffic flow, or reduce vehicle use or congestion with the objective of reducing air pollutant emissions. See **SIP.**

TDM (Transportation Demand Management) - In its most general form, any action or actions that attempt to control or alter existing travel patterns or use. Included in this group are a wide range of strategies, such as promoting ridesharing, requiring alternative workhours or flextime, or increasing travel costs for certain modes, mainly automobile, through parking controls or fees, or fuel taxes.

TIP (Transportation Improvement Program) - A program of transportation projects consistent with the transportation plan. Shows projects to be funded under federal programs for a 3-year period.

TMA (Transportation Management Association) - A voluntary association of public and private agencies and firms joined to develop cooperatively transportation programs in a given area. Appropriate organizations to manage transportation demand in congested suburban communities.

Transportation Plan - Required by ISTEA, a long-range document that identifies facilities and programs that should function as an integrated metropolitan transportation system and includes a financial plan, which demonstrates how the long-range plan can be implemented.

Travel Time Savings - The travel time savings that would be accrued by those transit users in the year 2020 who would be on the system before the improvements are made.

VMT (Vehicle Miles Traveled) - The number of miles traveled by roadway vehicles on the region's highway network.

Vehicle Service Hours - The sum of round trip running time and the layover time multiplied by the number of round trips each weekday, times the average train length.

Vehicle Service Miles - The total number of vehicle miles per weekday. This equals the round trip mileage times the number of round trips, times the average train length.

VOCs (Volatile Organic Compounds) - A group of chemicals that react in the atmosphere with NOx in the presence of heat and sunlight to form ozone. Examples include gasoline fumes and oil-based paints.

Appendix B
Policy Framework

This appendix presents transportation policies that are related to mass transportation. These policies were originally presented in the PMT Phase 2 report.

Mission Statement

The mission of the government agencies which plan, construct, maintain and operate the transportation system of Massachusetts is to maximize the mobility of people and goods. Mobility promotes economic vitality, allows for freedom of movement, and provides fair opportunity for all people to participate in society. These aims are integral to the welfare of the citizens of Massachusetts and to the competitiveness of firms which do business here.

Public transportation, the primary focus of this document, has the mission of moving large numbers of people in an efficient way, promoting economic vitality, but minimizing negative impact on the environment.

Policies of the transportation agencies translate this mission into the specific ways that the agencies maximize mobility. These policies must be periodically updated to recognize legislative mandates and other circumstances that affect investment decisions in the maintenance, operation, or expansion of the existing transportation system.

Legislative Context

Recent legislation at the Federal level influences current transportation policies. Three acts in particular affect transportation planning:

- The Americans with Disabilities Act of 1990.
- The Clean Air Act Amendments of 1990.
- The Intermodal Surface Transportation Efficiency Act of 1991.

The Americans with Disabilities Act mandates accessibility for all transportation facilities. The Clean Air Act Amendments set in place new deadlines for attaining air quality standards for ozone and carbon monoxide, the two most common air pollutants associated with mobile emissions sources. Finally, the Intermodal Surface Transportation Efficiency Act contains guidelines for transportation system planning with a clear emphasis on intermodal programs and management systems.

Intermodalism

To address the mandates set forth in these acts, the agencies which are responsible for the various components of the transportation system must work together to determine policies which are applicable to the system as a whole. While this policy document is principally concerned with public transportation, it must also consider other modes of travel which are interdependent with mass transit. Non-traditional transit modes such as high occupancy vehicles blur the distinction between transit and highways, reinforcing the need to take a broad perspective of the transportation system.

Outline of Policies

The policies of the transportation agencies are organized under five categories as outlined below. Neither the mission stated above nor the individual policies stated below are intended to stand on their own. Rather, the mission and policies taken as an integrated unit provide a basis for planning the future transportation system which maximizes mobility while minimizing negative impacts.

I. Transportation System Improvements

A. Maintain and upgrade the existing system.
B. Provide better integration between various components of the transportation system.
C. Reduce congestion on existing services and facilities.
D. Make existing services accessible to people with disabilities.
E. Ensure an equitable provision of services.
F. Ensure the safety and security of transportation system users.
G. Maximize the value of future investment.

II. Economic Vitality and Regional Development

A. Implement transportation investments that stimulate and sustain regional economic development.
B. Improve transportation in a manner that enhances the competitiveness of businesses and the economic vitality of communities and neighborhoods.
C. Encourage development in the urban core.
D. Support compact development.
E. Improve and develop the transportation system's ability to provide access in accordance with adopted land use plans.

III. Environmental Quality

A. Minimize air pollution.
B. Minimize water and soil pollution.
C. Minimize usage of land for transportation facilities.
D. Minimize noise and vibration impacts.
E. Minimize community disruption and negative visual impacts.
F. Encourage incorporation of public art in transportation facilities.

IV. Energy

V. Costs

I. Policy on Transportation System Improvements

The transportation system should provide mobility for all people in the region. Its principal role is to facilitate access to work locations, retail facilities, recreational areas and other destinations. It must also provide for the efficient movement of goods and services into and throughout the region.

A. Maintain and Upgrade the Existing System

Past investment in transportation facilities in the Boston region totals many billions of dollars. This investment has resulted in a system that people and firms rely on every day. Protecting that investment by maintaining and upgrading facilities and services which meet a demonstrated need is a top priority.

Maintenance is one of the most cost-effective uses of today's dollars, since a relatively small amount of money is needed to keep the system in good condition, compared to the amount that was spent to build it. Deferred maintenance may save money in the short run, but in the long run it may be more expensive than regular preventive maintenance. The value of regular maintenance resides not only in smoother, faster rides, but also in safety, longer equipment life and fewer breakdowns. Highway upgrades can improve safety and capacity; rail upgrades such as better track, better power distribution, better rolling stock and other innovative improvements can yield significant enhancements in mobility.

B. Provide Better Integration between Various Components of the Transportation System

One of the key goals of the recently enacted federal transportation legislation, the Intermodal Surface Transportation Efficiency Act of 1991, is to promote the integration of transportation modes, including auto, bus, carpool, vanpool, rail, boat, bicycle and pedestrian. This integration results in greater mobility because the various modes complement each other; the whole is greater than the sum of the parts.

Investment choices should be based in part on the way in which an improvement to a single transportation mode can make the system as a whole work better. There are a number of ways in which this can be done:

1. Improve Connections Between Modes to Maximize the Effective Use of Each Mode.

Connections between modes are crucial to the effectiveness of transportation services. Allowing for safe and convenient transfers between modes improves the overall efficiency of transportation by promoting a better distribution of travelers among available modes. This, in turn, can minimize congestion on a single mode and thus reduce average travel times. Connecting all parts of the system allows each part of the system to help the others; transit services help highways to function and vice versa. Common types of connections include walking to bus stops, biking to transit stations, and driving to park and ride facilities.

2. Improve Choices for Travelers in Specific Corridors by Providing Alternative Means of Travel.

Where demand is sufficient, new or improved services are important to encourage the use of transit or high occupancy vehicles (HOVs, i.e. carpools, vanpools and buses) as options within specific corridors. These new services should be carefully examined to assure that they are compatible with other modes within the same service area.

3. Encourage Public-Private Cooperation in the Provision of Transportation Services.

Business and employer assistance is essential to improve the use of transit and HOVs. Both private businesses and public agencies should work to encourage new riders and retain existing riders. Examples of this type of public-private cooperation include CARAVAN for Commuters, Inc.; the establishment of shuttle bus routes by private Transportation Management Associations (TMAs) and major employers; subsidizing private express commuter bus services; and public-private joint development and maintenance at commuter rail and transit stations.

4. Improve Marketing of Available Services.

Increased information on the effectiveness of public transportation, ridesharing or using HOVs on highways, bicycling, walking, as well as potential cost savings to riders, should be provided to the traveling public. This can be carried out on a regionwide basis by state agencies such as the MBTA and the Massachusetts Highway Department as well as private non-profit companies such as CARAVAN for Commuters, Inc., and by TMAs on a local basis.

C. Reduce Congestion on Existing Services and Facilities

Congestion on existing facilities results in wasted time, reduced efficiency and high levels of dissatisfaction among the traveling public. It also aggravates the air quality problems associated with transportation. To reduce congestion, transportation improvements should be directed towards relief of users of existing facilities and services, without restricting mobility or causing problems to occur at other locations. Examples of how this can be done are as follows:

1. Operate Existing Facilities More Effectively (Transportation Systems Management).

Existing facilities can be improved by providing better intermodal connections, and through operational improvements. Rail systems can be operated more efficiently by improving signal systems to allow higher speeds, by operating at more frequent headways, and by making other operational improvements. Bus lanes and traffic signal preemption for transit vehicles helps to reduce delays and congestion on individual buses and trains. Better operation of the highway system is now being addressed through congestion management efforts, including incident management, ramp metering and "intelligent vehicle highway systems" (IVHS) that exploit advanced technologies to improve management of fleet and user operation.

2. **Encourage Use of More Efficient Travel Modes by Improving the Attractiveness Of Mass Transportation Services and Providing Facilities For HOVs.**

   The attractiveness of various modes of travel depends on a number of factors including time, cost, comfort, reliability, security, convenience, flexibility, physical attractiveness, and so forth. Improvements in these areas help to make HOVs and mass transportation more competitive with single-occupancy vehicle travel.

3. **Improve facilities for bicyclists and pedestrians to encourage non-motorized transportation.**

   Improved conditions for bicycle travel on streets and highways, additional bicycle parking, expansion of the bikeway network and improvements to the pedestrian environment encourage people to use these alternative ways to travel. Wherever possible, new transportation projects should be planned to enhance the safety and attractiveness of bicycle and pedestrian travel in the project area.

4. **Encourage Employers to Participate in Congestion Reduction Programs (Transportation Demand Management).**

   Reduction of travel demand through employer based ridesharing efforts can be effective in alleviating congestion. Another program is flextime, which helps to shift peak period trips to off-peak periods. Telecommunications advancements may provide options to trip making.

5. **Expand Existing Facilities.**

   Expanding existing facilities is often the most direct way to alleviate congestion (although not always the most cost-effective). Transit capacity can be expanded by providing more frequent service, operating longer trains or higher capacity buses, and by adding parking at suburban stations. Highway capacity can be expanded by adding lanes, increasing the capacity of specific ramps or interchanges, or by adding incentives for HOVs such as head-of-queue privileges or HOV lanes.

6. **Improve Information Dissemination.**

   Improved methods of providing information about congestion trouble spots may make travelers more aware of the available options as to travel choices including route, mode, and time of travel. Advanced systems of telecommunication may also provide improved information concerning congestion.

D. Make Existing Services Accessible to People with Disabilities

Transit and paratransit systems must be made accessible to persons with physical or other disabilities in accordance with the Americans with Disabilities Act.

E. Ensure an Equitable Provision of Services

Transportation systems should be designed to provide equitable service and reinforce the economic and social vitality of the region's communities. Transportation investment decisions should be made through an open and participatory process which includes a broad representation of interested persons and groups.

F. Ensure the Safety and Security of Transportation System Users

Before using a part of the transportation system, travelers must be confident of a safe and secure trip, including the time spent in stations and in transfer between vehicles. Physical safety can be ensured through careful attention to design, redesign and upgrading of facilities and modes, and through effective maintenance. Operational safety can be ensured through adherence to proper operating procedures and through policing of facilities.

G. Maximize the Value of Future Investment

Transportation and land use have a symbiotic relationship—each needs and builds upon the other. This relationship entails a close compatibility of plans: transportation facilities should be built to serve well-developed land, and land should be developed more intensively where there are adequate transportation facilities. Transportation planning should take into account sound local and regional land use planning so that the projects with the greatest likely future benefits will be selected for present and future construction.

II. Policy on Economic Vitality and Regional Development

Transportation improvements must contribute to a healthy, active economy and serve as a stimulus for future growth. The transportation system should support economic development by assuring efficient, safe and reliable movement of employees and commerce throughout the region by reducing the time and cost of commuting, shipping goods, and other travel needs. Transportation service can enhance development opportunities. Thus the policy of economic vitality is closely linked with land use policies in supporting the investment in transportation infrastructure in concert with state and regional land use goals.

A. Implement Transportation Investments that Stimulate and Sustain Regional Economic Development

The transportation system is fundamental to and intertwined with economic activity. Transportation can support economic development by improving transit and highway access to developing areas, by increasing transportation services in economically disadvantaged areas and by locating transportation services in areas where new development is desired.

B. Improve Transportation in a Manner that Enhances the Competitiveness of Businesses and the Economic Vitality of Communities and Neighborhoods

Transportation facilities should aid in the beneficial and continual renewal of the businesses and communities that they serve. New transportation construction or improved transit accessibility can serve as the catalyst necessary to stimulate private investment, and encourage other public investment in these areas. Transportation improvements and new facilities should be undertaken in conjunction with local redevelopment efforts while being sensitive to the transportation impacts on the character of communities.

C. Encourage Development in the Urban Core

The economic health of the region is dependent on the vitality of the urban core because of the high concentration of economic activity in Boston, Cambridge, at Logan Airport and in the neighborhoods adjacent to these areas. The existing focus of transportation on the urban core, built up over three centuries, allows it to sustain a high density of commercial and residential development. This focus should be maintained and enhanced.

D. Support Compact Development.

Compact mixed-use development brings jobs, housing and shopping closer together. Trips are shorter, which encourages walking and bicycling. In addition, it is possible to institute some public transportation facilities because density is higher. Old cities of the region already have compact mixed-use development. These should be supported by transportation facilities in their effort to maintain or regain their economic vitality. The economic health of the region is also dependent on the vitality of the "edges" of the metropolitan area. Since an efficient intermodal transportation system is not in place in many of these areas, the public and private sectors should work together to develop such systems. Future development in edges of the metropolitan area should be encouraged when they contribute to and support the creation of such intermodal transportation systems.

E. Improve and Develop the Transportation System's Ability to Provide Access in Accordance with Adopted Land Use Plans

The transportation network should be improved by the provision of expanded transit and paratransit services to encourage new development in accordance with local and regional planning and policies. MetroPlan 2000, the land use plan for the Boston region created by the Metropolitan Area Planning Council, endorses concentrated development in areas already well-served by transportation infrastructure and is one guide for transportation planning and attendant development.

III. Policy on Environmental Quality

Transportation affects the environment by producing air pollution, by producing runoff that affects soil and drinking water, by taking up land, and by affecting communities with noise and visual impacts. The regional transportation system must be planned, designed, constructed, operated and maintained to preserve and enhance environmental quality.

A. Minimize Air Pollution.

1. Encourage Use of Efficient Travel Modes.

Air quality can be improved without impairing mobility by encouraging people to travel in those modes which reduce the average amount of emissions per passenger mile. A four-person carpool emits one quarter as much per passenger mile as a single occupant car, and a bus full of people a small fraction as much per passenger mile. Bicycle and pedestrian travel produces no emissions.

2. Encourage Use of Low Pollution Fuels and Engine Technology.

Alternative fuels and new engine technologies which emit fewer air contaminants should be developed and used wherever possible. Alternative fuel experimentation with fleet vehicles should continue and be implemented when it is judged to be feasible.

3. Achieve Mandated Air Quality Standards.

The Federal government has established air quality standards for carbon monoxide and ozone. The Clean Air Act Amendments of 1990 reestablish timetables for meeting these standards: for carbon monoxide by 1995 and for ozone by 1999. Nitrogen oxides, particulates and air toxins are also regulated by the amendments and may need to be reduced to comply with the Act. The amendments provide new guidance on how reductions will be achieved, and consistent with this, a new State Implementation Plan will be developed. The transportation agencies will play a major part in achieving these standards and will need to implement measures consistent with emission reduction goals.

B. Minimize Water and Soil Pollution

Design and construction of facilities should assure that materials used in operations and maintenance, such as road salt, as well as runoff containing petroleum products, trace metals, and particulates will not have serious impacts on soil and water.

C. Minimize Usage of Land for Transportation Facilities

Modes of travel which can transport many people with few vehicles typically use less land than modes which require many vehicles to transport many people. Examples include HOV lanes and transit lines. Of course, almost any facility can be made to take up less land by putting it underground or on air rights above existing facilities. This can be expensive and would only occur where land is extremely valuable and/or already densely developed.

D. Minimize Noise and Vibration Impacts

Although transportation facilities have great benefits for the region, they have some negative effects on the people living near them. Cars and trucks on expressways make a significant amount of noise, and trains make their presence known with track noise and a rumble of vibrations. These impacts can be mitigated with a variety of noise barriers and trackbed improvements. To the extent that it is feasible, noise and vibration impacts should be reduced.

E. Minimize Community Disruption and Negative Visual Impacts

There have been many instances where transportation structures have divided communities. Elevated roads and tracks, embankments and open cuts all inhibit access across rights-of-way to some extent. The trend in recent years has been to remove these barriers and this trend should continue. When possible, future elevated structures and embankments should be avoided. Transportation facilities should complement and build upon the existing historic and architectural character of the region. In planning new facilities, sensitivity to local design issues can help minimize adverse impacts on communities, neighborhoods and open spaces, through appropriate right-of-way treatment (landscaping, noise barriers, grade separation, etc.), and through other actions as identified in environmental studies.

F. Encourage Incorporation of Public Art in Transportation Facilities

The everyday act of commuting can be enhanced and the public experience can be expanded through the commissioning of the highest quality art in public spaces. Public awareness of the unique cultural and ethnic resources of communities surrounding transportation facilities can be enhanced by integrating art into the design of upgraded and new facilities. Such awareness would encourage a sense of public "ownership" and responsibility towards vandalism-proof installation. In addition, adequate art management and maintenance programs should be developed to protect the public investment.

IV. Policy on Energy

A. Minimize Use of Energy Resources

Efficient modes of travel such as transit and ridesharing save energy by using fewer vehicles to carry a given number of people. As vehicle occupancy rates increase, the amount of energy used per passenger mile decreases. Thus carpools are more efficient that single occupant cars, vanpools are more efficient than carpools, buses are more efficient than vanpools and trains are more efficient than buses. From this standpoint, pedestrian travel and bicycling are the most efficient since they use no fossil fuel or electricity at all. Research and development of alternatives to fossil fuels should be continued and their use be encouraged when feasible.

V. Policy on Costs

Transportation resources should be used as efficiently as possible. Funds from all sources are limited and should be expended so as to maximize mobility. The best way to ensure efficiency is to coordinate transportation agency activities through comprehensive planning and programming. This effort must achieve the following objectives:

- Achieve an optimal balance between mobility and total cost (including both capital and operating costs).
- Re-invest in existing assets where investment will assure continued usefulness while maintaining a compatibility with the environment.
- Undertake careful analysis of all projects including low-cost alternatives to each project.
- Expand the system using means of programming which give priority to projects which require a minimum of capital outlays, all other things being equal.
- Leverage private resources, wherever possible, to assist in providing services or facilities.
- Leverage federal funds where possible.

Appendix C

The Regional Transportation System

The Boston metropolitan area is served by a hub-and-spoke network of rapid transit, light rail, express bus, commuter rail and commuter boat lines. These services provide high quality and cost-effective commuting alternatives to the single-occupant automobile. Express and local bus, and trackless trolley services fill in the gaps between spokes by offering line-haul service in heavily congested areas, feeder services to rail, and inter-suburban linkages throughout the region. Centralized transportation for people with disabilities, provided by the MBTA, operates in 44 communities. In addition, many communities provide local transit services for their residents and for the elderly and disabled.

This appendix describes the many transit options available in the 164 communities making up the PMT study area. Trip-making within and to the MBTA district of 78 cities and towns constitute the majority of commuting trips in this geographic area. Maps of the MBTA district and the PMT study area are shown in Figures C-1 and Figure C-2 .

The Existing Transit System

The MBTA operates a system made up of seven different modes: rapid transit, light rail, local/express bus, trackless trolley, commuter rail, paratransit vans and commuter boat. With the exception of commuter rail, all routes are contained entirely within the MBTA district. Commuter rail service operates on 11 lines,[1] eight of which extend beyond the MBTA district. In total, 55 communities[2] are directly served, twenty of which are outside the MBTA district. In addition, 20 private carriers, 8 regional transit authorities[3] (including the MBTA) and 10 localities provide inter-district and/or local bus services throughout the study area. Three ferry routes[4] carry commuters from the Charlestown Navy Yard, Hingham and Hull to downtown Boston. Lastly, The RIDE offers accessible van service to 44 communities.

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[1] The Ipswich and Stoughton branches are counted separately.

[2] Hamilton and Wenham are both considered to have direct service, although the station lies wholly within the town of Hamilton.

[3] Cape Ann, Merrimack Valley, Lowell, Montachusett, Worcester, Greater Attleborough/ Taunton and Brockton.

[4] A fourth route between Rowes Wharf and Logan airport is not considered a commuter service and therefore is not discussed here.

Figure C-1
MBTA Service District: 78 Communities

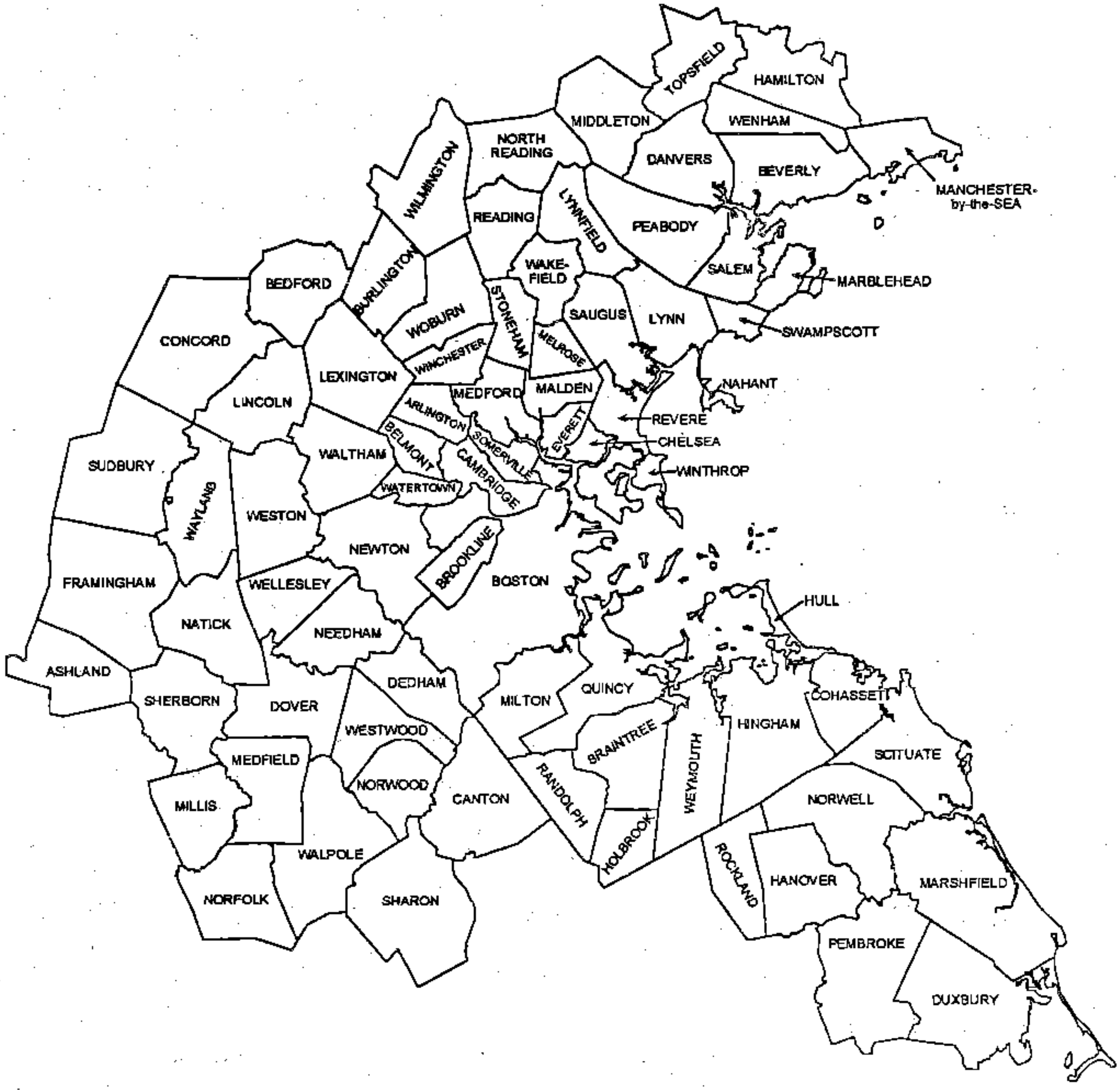
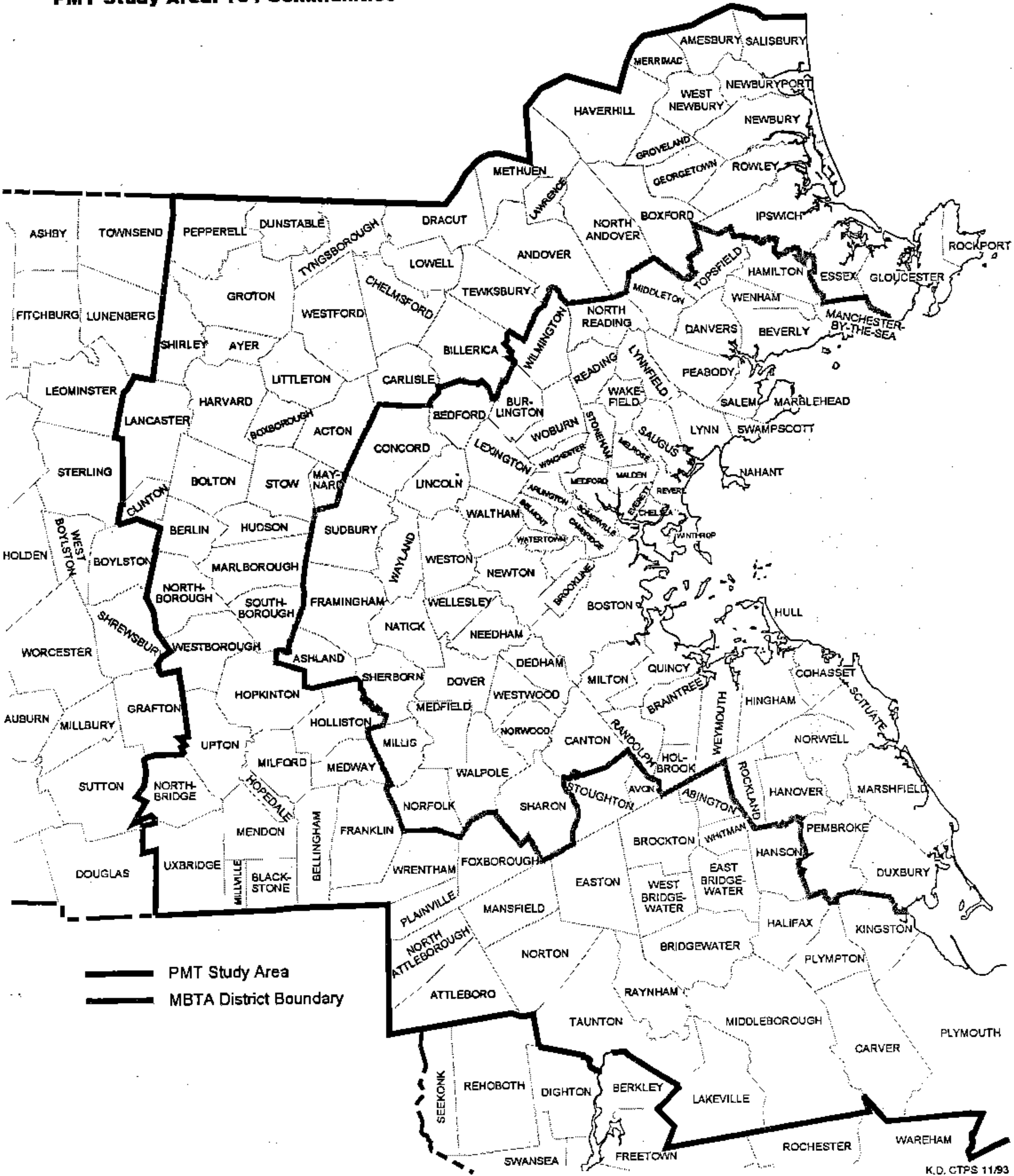


Figure C-2
PMT Study Area: 164 Communities



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Systemwide, approximately 11,000 vehicle[5] trips are made daily between the hours of 5:00 am and 2:00 am. Service and ridership statistics presented in this chapter were gathered from various sources including the MBTA's Ridership and Service Statistics (November 1991), and the Central Artery/Tunnel Project Regional Transit Mitigation Program, prepared by Vanasse Hangen Brustlin, Inc. for the MBTA (September 1991).

Rapid Transit and Light Rail

The MBTA rapid transit and light rail systems are comprised of 125 stations on four lines: the Red Line, the Orange Line, the Blue Line and the Green Line. All lines provide service to downtown Boston and all lines directly connect with each other, except for the Red and Blue lines. See Figure C-3. Daily ridership on the rapid transit/light rail system is approximately 562,000 trips per weekday. (All ridership data is a composite average for FY 1991 and reported as unlinked trips.)

Red Line

Of the three rapid transit lines, the Red Line is the longest, 21 miles, and the most heavily utilized, generating an average 185,000 trips per weekday. Twenty-two stations comprise the Red Line, 14 of which are accessible (improvements to Andrew station are underway). Service runs on two branches, between Alewife Station in North Cambridge and Ashmont Station in Dorchester or Braintree Station in Braintree. All service operates along a common alignment between Alewife and the JFK/UMass Station in Dorchester, at which point service branches off to either Ashmont or Braintree. Throughout most of the day, service is split equally between the two branches. The MBTA runs 6-car and 4-car trains during the a.m. and p.m. peak hours and 4-car trains at other times. There are 214 cars in the Red Line fleet, all of which are accessible. During the peak hour, 160 passengers per car is considered design load. Park-and-ride facilities provide 8,404 parking spaces. Rush hour trains operate at 8 minute intervals from Braintree and Ashmont and at 4 minute intervals between JFK/UMass and Alewife. Average speed on the Braintree and Ashmont branches are 23.3 mph and 19.2 mph respectively. Peak hour capacity totals 12,200 passenger trips.

Mattapan High Speed Line

The Mattapan High Speed Line connects with the Red Line and operates between Ashmont and Mattapan using PCC light rail vehicles. The line can be considered an extension of the Red Line in most respects, but its vehicles are maintained and operated as part of the Green Line fleet. The Mattapan High Speed Line utilizes 12 light rail vehicles, run as single cars. The line, 2.7 miles long, is comprised of eight stations, 299 parking spaces and generates 7,000 passenger trips per weekday.

Orange Line

The Orange Line is 11 miles long and operates between Oak Grove in Malden and Forest Hills in Jamaica Plain. At nineteen stations, 13 of which are accessible, 127,000 trips are generated each day. The segment between Chinatown and Forest Hills, relocated in 1987, is approximately 4.7 miles long with eight stations. This portion

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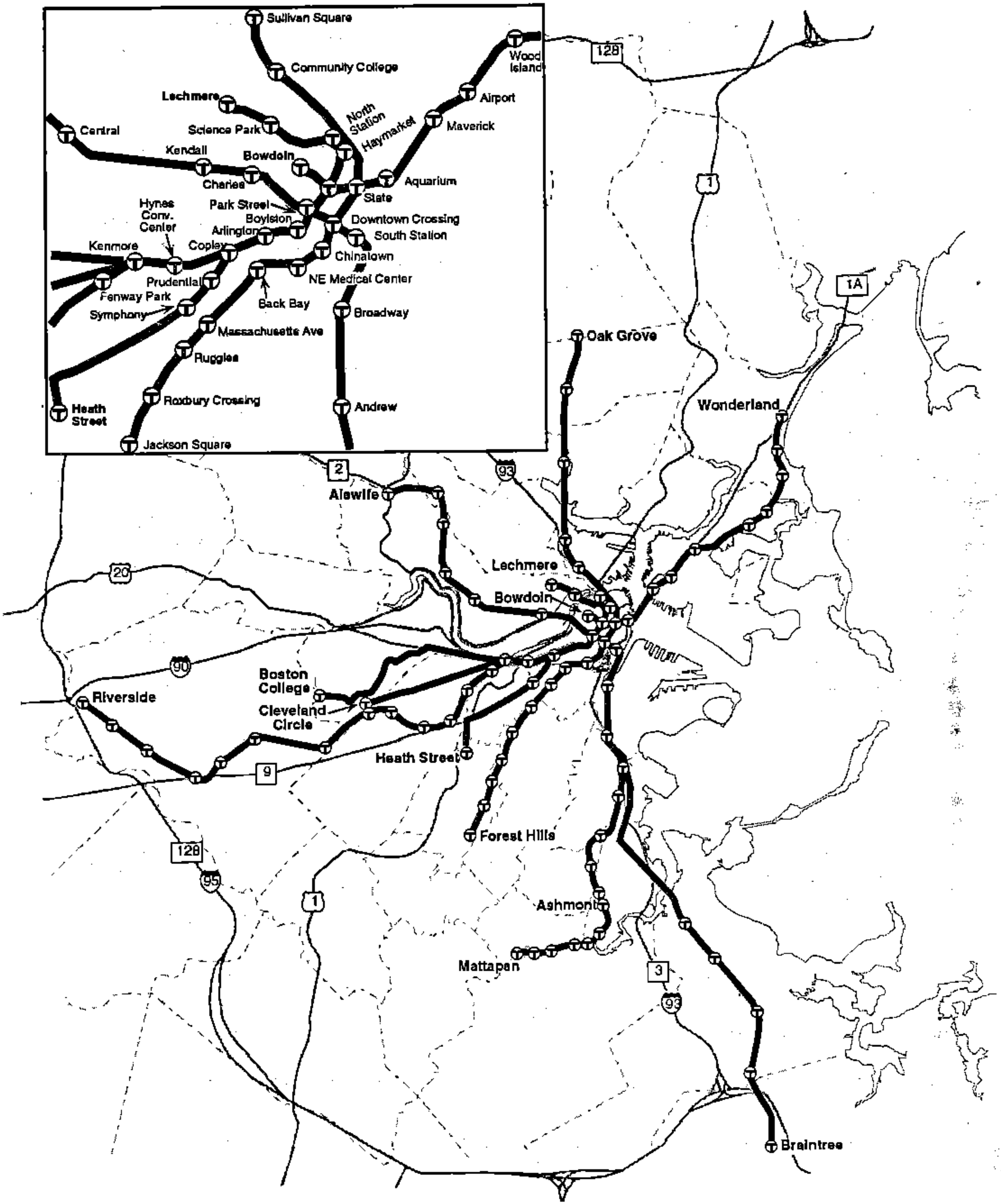
[5] A vehicle is defined as a single car. A 6-car Red Line train trip is equivalent to 6 vehicle trips.

Figure C-3
MBTA Rapid Transit and Light Rail System



shares the right-of-way with commuter rail, which also uses three of the eight stations. The Orange Line fleet consists of 120 vehicles, all of which are accessible. During the peak hour, 130 passengers per car is considered design load. Park-and-ride facilities provide 2,629 spaces. The MBTA runs 6-car trains during the a.m. and p.m. peak hours and 4-car trains at all other times. Rush hour trains operate at 5 minute intervals at an average speed of 20.2 mph. Peak hour capacity is approximately 9,400 passenger trips.

Blue Line

The six mile long Blue Line is the shortest of the three rapid transit lines and operates between Wonderland Station in Revere and Bowdoin Station in the Government Center area of Boston. Twelve stations, two of which are accessible, generate 54,000 weekday trips. The Blue Line fleet consists of 70 cars, all of which are accessible. During the peak hour, 95 passengers per car is considered the design load. Park-and-ride facilities provide 2,334 spaces. Rush hour trains operate at 3 minute intervals at an average speed of 18.7 mph. All trains are 4 cars in length at all times. Peak hour capacity totals 7,600 passenger trips.

Green Line

The Green Line, which uses light rail vehicles (LRVs), generates approximately 189,000 trips per weekday over 23 miles of track. The line is comprised of seventy stations, 13 of which are subway or elevated/at grade. None of the stations are accessible. The remaining 57 are surface stops on four branches to the west and southwest of downtown Boston: the Boston College branch (B Line), the Cleveland Circle branch (C Line), the Riverside branch (D Line), and the Arborway branch (E Line). All branches operate to their named terminals with the exception of the Arborway branch which now terminates at the intersection of Heath Street and South Huntington Avenue. The northern terminus of the Green Line is at Lechmere Station in Cambridge, but only Heath Street/Arborway trains operate that far. Because ridership north of downtown Boston is much lower than to the west and southwest, Boston College and Riverside trains turn around at Government Center, and Cleveland Circle trains turn around at North Station. There are 217 LRVs in the Green Line fleet, none of which are accessible. During the peak hour, 110 passengers per car is considered design load. Park-and-ride facilities provide 2,123 spaces. Rush hour trains operate at 5 to 8 minute intervals on the four branches and at 1.3 minute intervals between Copley and Government Center stations. Peak hour capacity totals 9,800 passenger trips.

Improvements to the rapid transit system have resulted in increased capacity and better service coverage. Examples include the new Orange Line and the Red Line Extension to Alewife. In addition, the MBTA completed station modernizations and platform extensions to accommodate 6-car trains on the Red and Orange lines thereby increasing peak hour capacity by 50 percent. (Planning has already begun to extend Blue Line platforms to accommodate six car trains.) Between FY 1986 and FY 1991, A.M. peak period deployment has been increased from 248 to 312 cars on the Red, Orange, and Blue Lines, and from 101 to 142 cars on the Green Line and Mattapan High Speed Line (see Table C-1). Overall peak period frequency of service from the termini on these rapid transit and light rail lines range from 3 to 8 minutes.

In addition, major track improvements were recently completed on the Red and Green lines, as well as power and signal improvements on the Green Line, in order to improve the reliability of those lines. Work has recently begun on a relocation of the Green Line

Table C-1
Rapid Transit and Light Rail Lines Peak Period Service Levels (FY 1992)

	Fleet Size (# Cars)	Trains	Consist (# Cars/ Train)	Peak Service Req'mt (# cars)	Headway (Minutes)
RED LINE	214	29	4, 6	150	4
Ashmont		7	4	28	8
		5	6	30	
Braintree		5	4	20	8
		9	6	54	
Run-as-Directed		3	6	18	
MATTAPAN	12	6	1	6	4
ORANGE LINE	120	17	6	102	5
BLUE LINE	70	15	4	60	3
GREEN LINE	217	75	1-2	136	1.3
Boston College		21	2	42	5
Cleveland Circle		14	2	28	6
Riverside		16	2	32	6
Reservoir		10	1	10	6
Heath Street		10	2	20	8
Run-as-Directed		4	1	4	

Note: 1.3 minute Green Line headway is between Government Center and Copley, and 4 minute Red Line headway is between Alewife and JFK/UMass.

between North Station and Science Park to replace the current elevated service with subway service, and to provide cross platform connections with the Orange Line and improved connections with commuter rail at the new North Station. For a more detailed discussion of past improvements and those currently underway see Appendix D.

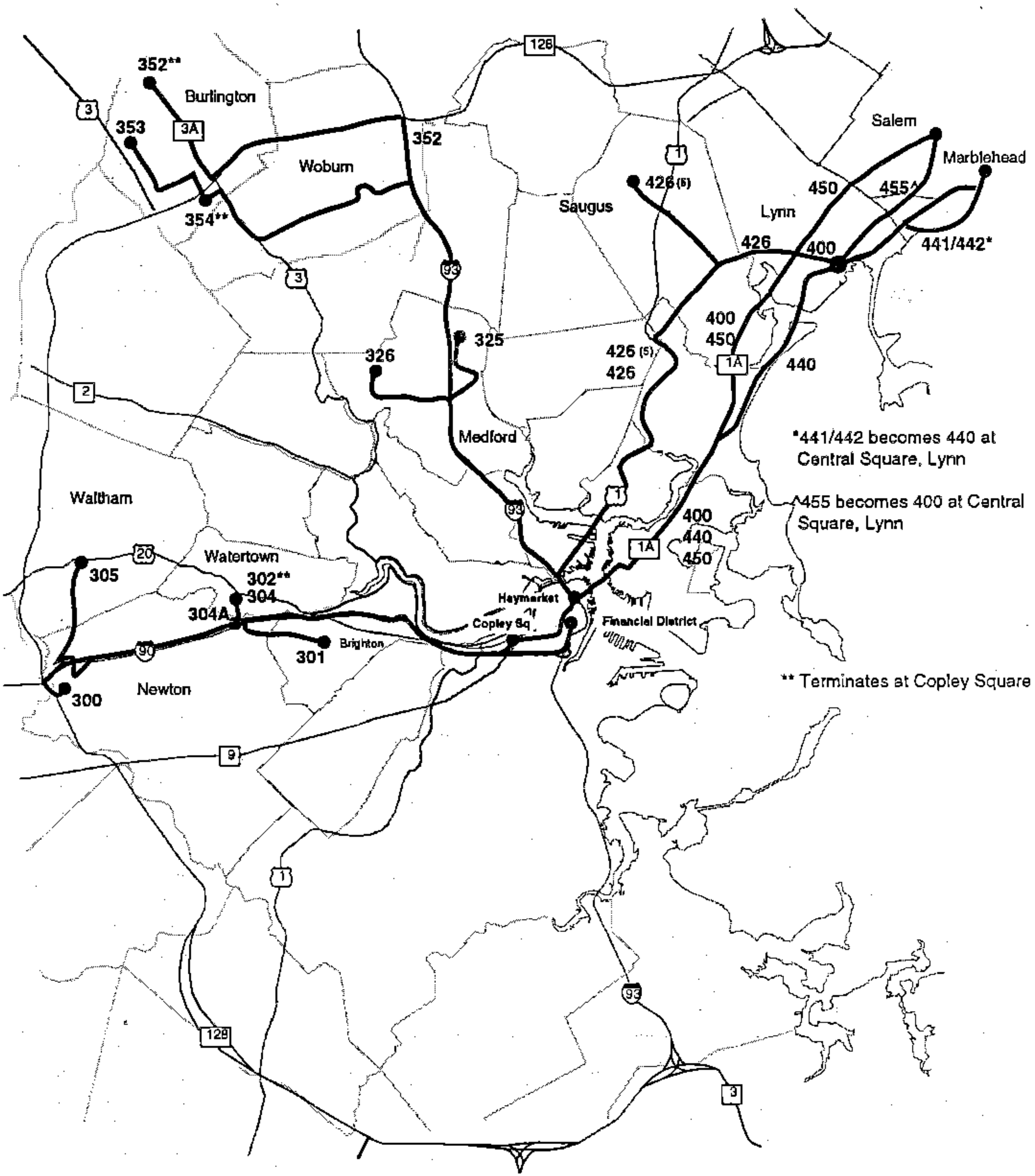
Bus And Trackless Trolley

The MBTA operates 159 bus routes throughout the MBTA district, including four trackless-trolley lines in Cambridge, Watertown and Belmont. In FY 1991, total bus ridership was approximately 360,000 trips per weekday.

Nearly all routes connect with the rapid transit system at, at least, one location. In areas closer to Boston, bus service provides crosstown service, feeder service to rapid transit stations, and line haul service in heavily congested areas. Further out, buses provide local service and connections to rapid transit and some commuter rail lines. There are 952 buses and 38 trackless trolleys in the MBTA's active fleet, of which 473 are lift equipped.

The MBTA operates express bus routes service from 11 communities: Newton, Watertown, Waltham, Medford, Burlington, Woburn, Lynn, Marblehead, Salem, Saugus and the

Figure C-4
MBTA Express Bus Routes



*441/442 becomes 440 at Central Square, Lynn

^455 becomes 400 at Central Square, Lynn

** Terminates at Copley Square

Boston neighborhood of Brighton. Specific routes include the 300, 301, 302, 304, 304A, 305, 325, 326, 352, 353, 354, 426, 441, 442, 450, and 455 (see Figure C-4). Note that at Central Square in Lynn the 441/442 and the 455 routes become the 440 and the 400 respectively. In 1991, typical weekday boardings on all express routes totaled 25,300 trips.

Buses serve over 10,000 stops, 314 of which are equipped with bus shelters. One park-and-ride lot in Arlington provides 194 parking spaces. The present MBTA bus network consists mostly of routes taken over from several previous operators. Most of these routes have lengthy histories, and many had their origins as streetcar lines built before 1900. Schedules and route alignments have been revised gradually over the years, but most continue to operate along the same general alignments in response to continuing demand. A list of MBTA bus routes and FY 1992 service levels is shown below in Table C-2. (Note: several MBTA bus routes that serve specific industrial areas are not listed in the table.)

Table C-2
MBTA Bus Routes and FY 1992 Weekday Service Frequencies (in minutes)

Route #	Route Name	Rush Hours	Mid-day	Night
1	Harvard–Dudley Square via Mass Ave	7/7	12	16
3	Boston Marine Industrial Park–Chinatown	20/22	-	-
5	City Point–McCormack Housing Project	-	60	-
6	Boston Marine Ind. Park–Haymarket & South Station	30/30	30	-
7	City Point–Downtown via Northern Avenue	12/14	25	40
8	UMass–Ruggles Station via Edw. Everett Square	20	60	45
8A	Dudley Sq.–Kenmore Sta. via Longwood Medical Area	7/10	25	-
9	City Point–Copley Square via Broadway	8/9	15	30
10	City Point–Copley Square via Andrew & Southampton	25/25	35	60
11	City Point–Downtown	5/7	15	30
14	Roslindale Square–Dudley Square via Blue Hill Ave	60/60	60	60
15	Kane Square or Fields Corner–Ruggles via Uphams Corner	7/9	13	30
16	Forest Hills–UMass via Andrew	16/15	30	50
17	Fields Corner–JFK Station or Ruggles Sta. via Geneva Avenue	15/15	20	L
18	Ashmont–Broadway via Dorchester Ave	35/35	70	-
19	Fields Corner–Ruggles via Warren Street & Grove Hall	13/20	70	-
20	Fields Corner–Neponset & Adams Belt Line	12/30	30	30
21	Ashmont–Forest Hills via Morton Street	11/11	20	40
22	Ashmont–Ruggles Station via Jackson Square	6/7	13	20
23	Ashmont–Ruggles Station via Washington	5/6	13	20
24	Wakefield Avenue–Mattapan	20/25	50	60
26	Ashmont–Norfolk & Morton Belt Line	30/30	30	-
27	Mattapan–Ashmont via River Street	30/30	30	30
28	Mattapan–Ruggles Station via Dudley Square	8/8	12	20
29	Mattapan–Jackson Square Station	16/15	60	-
30	Mattapan–Roslindale Square via Cummins Highway	20/20	30	60
31	Mattapan–Forest Hills	8/8	12	20
32	Wolcott Sq.–Forest Hills via Cleary Sq./Hyde Park Ave.	12/14	15	30
32A	Cleary Sq.–Forest Hills via Hyde Park Ave.	12/14	-	-
33	Dedham Line–Mattapan via River Street	60/60	60	-
34	Dedham–Forest Hills via Washington Street	9/7	30	60
34E	Walpole Ctr.–Forest Hills via Washington Street	20/20	30	60

Table C-2 (Continued)
MBTA Bus Routes and FY 1992 Weekday Service Frequencies (in minutes)

Route #	Route Name	Rush Hours	Mid-day	Night
236	Quincy Center–South Shore Plaza via Braintree Station	L/30	60	-
238	Quincy Center–Crawford Sq., Randolph via Quincy Adams	30/30	60	60
240	Avon–Ashmont via Randolph	20/20	60	60
240A	Crawford Square–Ashmont	20/20	60	-
245	Quincy Center–Mattapan via Quincy Hospital	30/30	60	-
301	Brighton Center–Downtown Express via Oak Sq & Mass Pike	4/5	-	- X
302	Watertown Square–Copley Square Express via Mass Pike	10/12	-	- X
304	Watertown Square–Downtown Express via Mass Pike	8/10	30	- X
305	Waltham Center–Downtown Express via Mass Pike	6/8	-	- X
325	Elm Street, Medford–Haymarket Express via I-93	10/12	-	- X
326	West Medford–Haymarket Express via I-93	10/12	-	- X
350	Burlington/Billerica Line–Alewife via Arlington Center	14/20	60	60
352	Burlington–Haymarket or Park Square Express via 128 & I-93	10/15	-	- X
353	Burlington Industrial Area–Haymarket via Woburn Center	30/25	-	- X
354	Woburn Center–Haymarket or Park Square Express via I-93	10/15	-	- X
400	Lynn–Haymarket via Lynn Common	15/15	30	60 X
411	Malden Station–Revere House via Granada Highlands	35/50	60	-
426	Lynn & East Saugus–Haymarket Express via Cliftondale	15/15	60	80 X
429	Central Square, Lynn–North Saugus	30/30	60	-
430	Appleton St, Saugus–Malden Station via Saugus Center	40/45	60	-
433	Pine Hill–Central Square, Lynn	40/40	L	-
435	Lynn–Danvers via NS Shopping Center & Liberty Tree Mall	L/L	60	-
436	Happy Valley–Central Square, Lynn	30/30	60	-
437	Lake Shore–Central Sq. Lynn via Eastern Ave & Lake Side	30/30	60	-
439	Central Square, Lynn–Nahant	30/30	L	-
440	Lynn–Haymarket via Lynnway & General Edwards Bridge	15/10	30	60 X
441	Marblehead–Downtown via Paradise Rd & Central Sq, Lynn	30	60	- X
442	Marblehead–Downtown via Humphrey St & Central Sq, Lynn	30	60	60 X
450	Salem–Haymarket via Highland & Western Avenue	10	60	L X
451	North Beverly–Salem	60	60	-
455	Salem–Haymarket via Central Square, Lynn	30	30	60 X
458/ 468	Salem Center–Danvers via Liberty Tree Mall & Endicott Plaza	60	60	-

L=Limited Service
X=Express Bus Route

Commuter Rail

The 265-mile commuter rail network is comprised of 11 radial lines, with 101 stations (see Figure C-5). In FY 1991, daily ridership was approximately 74,600 trips per day. The commuter rail system is split into two sides. Northside service operates to and from North Station, and southside service to and from South Station. The Mass. Turnpike can be considered the dividing line between North and South Station service: all routes north of

Table C-2 (Continued)
MBTA Bus Routes and FY 1992 Weekday Service Frequencies (in minutes)

Route #	Route Name	Rush Hours	Mid-day	Night
86	Sullivan–Cleveland Circle via Harvard Square	20/20	30	60
87	Arlington Center–Lechmere via Clarendon Hill	16/15	30	30
88	Clarendon Hill–Lechmere via Highland Avenue	7/12	30	30
89	Clarendon Hill–Sullivan via Broadway	9/10	30	60
90	Davis Square–Wellington via Sullivan & Assembly Sq Mall	30/35	70	60
91	Sullivan–Central Square, Cambridge via Washington St	25/25	25	60
92	Assembly Square Mall–Downtown via Sullivan & Haymarket	10/13	30	L
95	West Medford–Sullivan via Mystic Avenue	15/15	30	60
96	Medford Square–Harvard via Davis	20/20	40	60
97	Malden–Wellington via Commercial and Hancock Streets	30/30	60	-
99	Upper Highland Avenue–Wellington via Main Street	20/20	30	60
100	Elm Street–Wellington via Fellsway	20/20	20	60
101	Malden Station–Sullivan via Salem St, Main St, & Broadway	15/12	30	60
104	Malden Station–Sullivan via Ferry Street	12/15	30	60
105	Malden Station–Sullivan via Faulkner & Main Streets	30/30	60	-
106	Lebanon Street, Malden–Wellington via Main Street	20/20	30	60
108	Linden Square–Wellington via Malden St & Highland Ave	20/25	30	60
109	Linden Square–Sullivan Square via Broadway	12/15	30	60
110	Wonderland or Broadway/Park–Wellington via Park Ave	20/20	30	60
111	Woodlawn–Haymarket via Mystic Bridge & Tobin Bridge	6/8	15	15
112	Wellington–Maverick via Central Ave & Mystic Mall	35/35	35	-
116	Wonderland–Maverick via Revere Street	17/20	30	60
117	Wonderland–Maverick via Beach Street	17/20	30	60
119	Northgate–Beachmont via Revere Center	30/30	60	40
120	Orient Heights–Maverick via Bennington Street	13/15	20	60
121	Wood Island–Maverick via Lexington Street	30/25	-	-
130	Lebanon Street, Melrose–Malden Station via Forestdale	30/30	60	-
131	Melrose Highland–Malden Station via Oak Grove Station	30/30	60	-
134	North Woburn–Wellington via Medford Square	60/60	60	-
134M	Medford Square–Wellington Station	40/20	60	-
136	Reading Square–Malden Station via Lakeside & Oak Grove	30/45	70	L
137	Reading Square–Malden Station via North St & Oak Grove	30/30	70	80
210	Quincy Center–Fields Corner via North Quincy	30/30	30	-
211	Quincy Center–Squantum via North Quincy	L/30	60	-
212	Quincy Center–North Quincy via Billings Road	30/60	-	-
214	Quincy Center–Germantown via Sea Street & Oceanview	12/20	30	-
215	Quincy Center–Ashmont via East Milton Square	20/30	30	60
216	Quincy Center–Houghs Neck via Sea Street	9/20	30	60
217	Wollaston Beach–Ashmont via Wollaston	30/30	60	-
220	Quincy Center–Hingham	10/10	60	60
221	Fort Point–Quincy Center	L/L	-	-
222	Quincy Center–East Weymouth	11/15	30	60
225	Quincy Center–Weymouth Landing via Des Moines Road	20/20	60	60
225A	Quincy Center–Weymouth Landing via Quincy Avenue	20/20	60	-
230	Quincy Cntr–Brockton Line via Holbrook & Braintree Sta.	20/20	60	60

Table C-2 (Continued)
MBTA Bus Routes and FY 1992 Weekday Service Frequencies (in minutes)

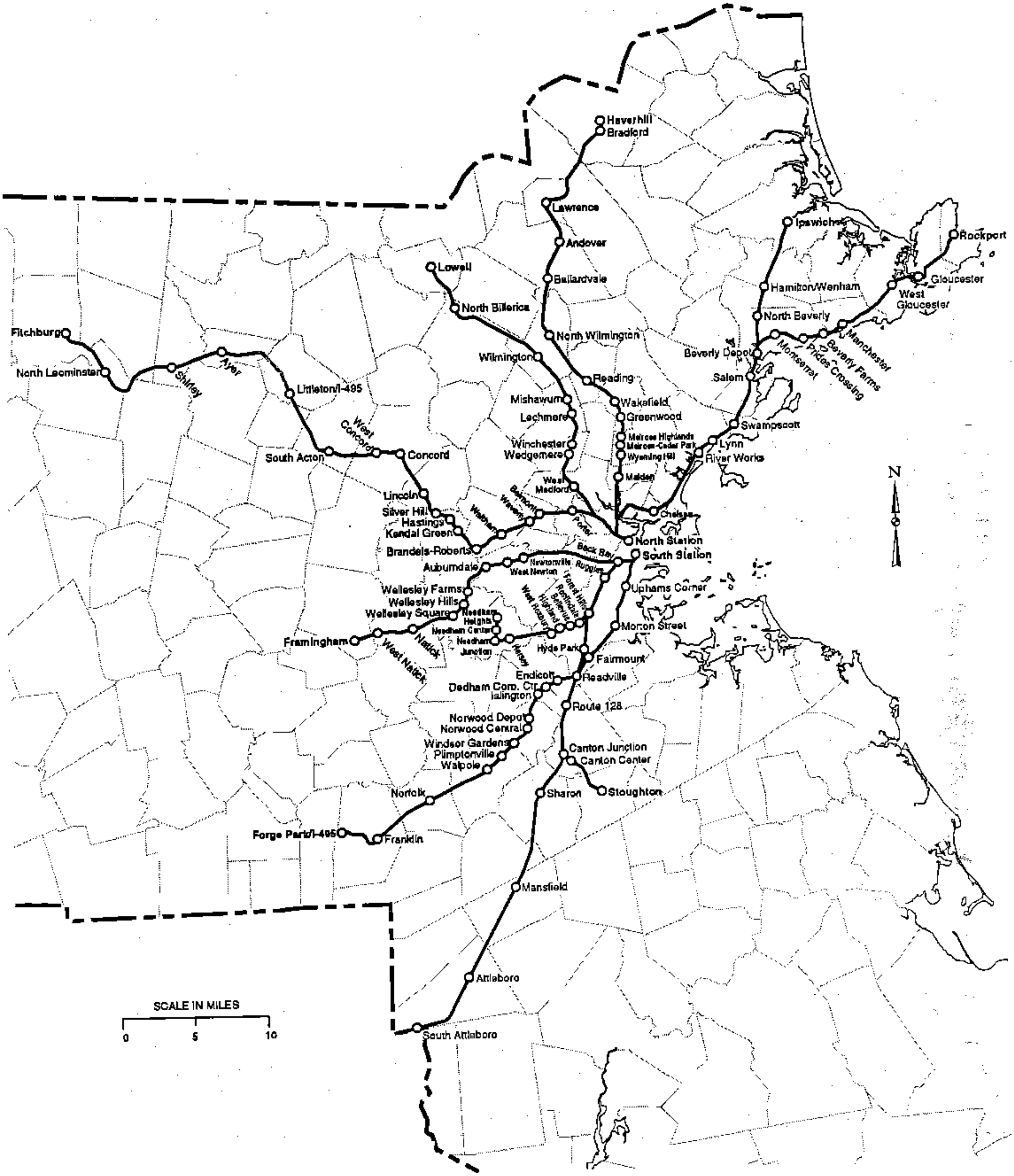
Route #	Route Name	Rush Hours	Mid-day	Night
236	Quincy Center–South Shore Plaza via Braintree Station	L/30	60	-
238	Quincy Center–Crawford Sq., Randolph via Quincy Adams	30/30	60	60
240	Avon–Ashmont via Randolph	20/20	60	60
240A	Crawford Square–Ashmont	20/20	60	-
245	Quincy Center–Mattapan via Quincy Hospital	30/30	60	-
301	Brighton Center–Downtown Express via Oak Sq & Mass Pike	4/5	-	- X
302	Watertown Square–Copley Square Express via Mass Pike	10/12	-	- X
304	Watertown Square–Downtown Express via Mass Pike	8/10	30	- X
305	Waltham Center–Downtown Express via Mass Pike	6/8	-	- X
325	Elm Street, Medford–Haymarket Express via I-93	10/12	-	- X
326	West Medford–Haymarket Express via I-93	10/12	-	- X
350	Burlington/Billerica Line–Alewife via Arlington Center	14/20	60	60
352	Burlington–Haymarket or Park Square Express via 128 & I-93	10/15	-	- X
353	Burlington Industrial Area–Haymarket via Woburn Center	30/25	-	- X
354	Woburn Center–Haymarket or Park Square Express via I-93	10/15	-	- X
400	Lynn–Haymarket via Lynn Common	15/15	30	60 X
411	Malden Station–Revere House via Granada Highlands	35/50	60	-
426	Lynn & East Saugus–Haymarket Express via Cliftondale	15/15	60	80 X
429	Central Square, Lynn–North Saugus	30/30	60	-
430	Appleton St, Saugus–Malden Station via Saugus Center	40/45	60	-
433	Pine Hill–Central Square, Lynn	40/40	L	-
435	Lynn–Danvers via NS Shopping Center & Liberty Tree Mall	L/L	60	-
436	Happy Valley–Central Square, Lynn	30/30	60	-
437	Lake Shore–Central Sq. Lynn via Eastern Ave & Lake Side	30/30	60	-
439	Central Square, Lynn–Nahant	30/30	L	-
440	Lynn–Haymarket via Lynnway & General Edwards Bridge	15/10	30	60 X
441	Marblehead–Downtown via Paradise Rd & Central Sq, Lynn	30	60	- X
442	Marblehead–Downtown via Humphrey St & Central Sq, Lynn	30	60	60 X
450	Salem–Haymarket via Highland & Western Avenue	10	60	L X
451	North Beverly–Salem	60	60	-
455	Salem–Haymarket via Central Square, Lynn	30	30	60 X
458/468	Salem Center–Danvers via Liberty Tree Mall & Endicott Plaza	60	60	-

L=Limited Service
X=Express Bus Route

Commuter Rail

The 265-mile commuter rail network is comprised of 11 radial lines, with 101 stations (see Figure C-5). In FY 1991, daily ridership was approximately 74,600 trips per day. The commuter rail system is split into two sides. Northside service operates to and from North Station, and southside service to and from South Station. The Mass. Turnpike can be considered the dividing line between North and South Station service: all routes north of

Figure C-5
MBTA Commuter Rail Lines



the Turnpike—the Rockport, Ipswich, Haverhill, Lowell, and Fitchburg lines operate to and from North Station. Lines along the Mass. Turnpike or to the south—the Framingham, Needham, Franklin, Attleboro/Providence, Stoughton, and Fairmount lines – operate to and from South Station. All southside lines except the Fairmount Line also serve Back Bay Station.

The commuter rail fleet consists of 52 locomotives and 303 coaches, 291 of which are accessible. As shown in Table C-3, a total of 109 peak weekday inbound and outbound trips are scheduled, with headways ranging from 25 to 40 minutes during peak periods, and from one to four hours during off-peak times. Seventy-five double-decker cars entered service in 1992. Over 17,600 park-and-ride spaces are provided, or under construction, for commuter rail riders. See Commuter Parking section for a detailed breakdown.

Table C-3
FY 1992 Commuter Rail Service Levels

	Weekday Trips			Saturday	Sunday
	In	Out	Headways	Trips	Trips
North Side Service					
Fitchburg Line					
Peak	5	5	40 minutes	8	7
Off Peak	11	11	2 hours	8	7
Total	16	16		16	14
Lowell Line					
Peak	5	5	30 minutes	8	8
Off Peak	17	17	1 hour	8	8
Total	22	22		16	16
Haverhill Line					
Peak	7	6	25 minutes	6	6
Off Peak	15	16	2-3 hours	6	6
Total	22	22		12	12
Ipswich Line					
Peak	4	3	30 minutes	5	7
Off Peak	8	9	2 hours	5	7
Total	12	12		10	14
Rockport Line					
Peak	3	4	30 minutes	7	7
Off Peak	9	8	2 hours	7	7
Total	12	12		14	14
North Side Totals					
Peak	24	23	25-40 minutes	34	35
Off Peak	60	61	1-3 hours	34	35
Total	84	84		68	70
South Side Service					
Framingham Line					
Peak	5	4	30 minutes	9	7
Off Peak	10	12	2 hours	9	7
Total	15	16		18	14

Table C-3 (Continued)
FY 1992 Commuter Rail Service Levels

	Weekday Trips			Saturday Trips	Sunday Trips
	In	Out	Headways		
Needham Line					
Peak	5	5	30 minutes	9	7
Off Peak	12	12	2 hours	9	7
Total	17	17		18	14
Franklin Line					
Peak	6	5	30 minutes	9	7
Off Peak	12	12	2 hour	9	7
Total	18	17		18	14
Attleboro Line					
Peak	6	5	25 minutes	9	7
Off Peak	10	11	2-3 hours	9	7
Total	16	16		18	14
Stoughton Line					
Peak	4	4	30 minutes	-	-
Off Peak	11	11	1 hour	-	-
Total	15	15		-	-
Fairmount Line					
Peak	6	6	30 minutes	-	-
Off Peak	17	15	2 hours	-	
Total	23	21		-	-
South Side Totals					
Peak	32	29	25-40 minutes	36	28
Off Peak	72	73	1-3 hours	36	28
Total	104	102		72	56
North & South Side Totals					
Peak	56	52	25-40 minutes	70	63
Off Peak	132	134	1-3 hours	70	63
Total	188	186		140	126

Commuter Boat

Commuter boat service operates between Hingham and Rowes Wharf (Boston), the Charlestown Navy Yard and Long Wharf (Boston), and from Point Pemberton in Hull.

The majority of service between Hingham and Boston is operated by Boston Harbor Commuter Service using five vessels: two with a capacity of 320 passengers, and three with a capacity of 150 passengers. Operating between 6:00 a.m. and 8:00 p.m., 17 inbound trips and 17 outbound trips, with peak period frequency every 15 to 20 minutes, are made per day. Average daily ridership, in FY 1991 approximated 2,200 trips. A second operator, Mass Bay Lines provides unsubsidized service along the same route. Approximately 1,350 parking spaces are provided among several lots at the Hingham Shipyard.

Ferry service from the Charlestown Navy Yard to Long Wharf is operated by Boston Harbor Cruises with funding provided by the Massachusetts Department of Highways.

Two 38-passenger vessels handle approximately 611 passenger trips per weekday. Also at the Navy Yard, Reliable Bus Lines operates shuttle bus service with connections to the ferry.

Other private commuter boat service between the South Shore and Boston is provided by Bay State Cruises, from Point Pemberton in Hull. Bay State Cruises operates one inbound and one outbound trip per day. A separate boat service, operated by Nantransit from Nantasket Pier in Hull, was recently suspended.

Suburban Bus

The suburban bus program is geared toward low density communities where regular MBTA service would not be cost-effective. Through this program, the MBTA provides funding and technical assistance to suburban communities that operate local transit services. The program, begun in 1979, subsidizes 10 communities: Bedford, Beverly, Burlington, Dedham, Framingham, Lexington, Lynn, the Mission Hill neighborhood of Boston, Natick and Norwood. Service in Needham has been temporarily suspended. Average weekday ridership in FY 1991 totaled 1,875 trips. Table C-4 summarizes the MBTA Suburban Bus Program.

Private Carrier Bus Service

A total of 20 private bus carriers provide commuter service on 34 routes within the PMT study area of 164 communities, the majority of which are radial trips to downtown Boston. These carriers provide fixed route service to communities that, for the most part, are not directly served by MBTA bus or rail.

Operators providing Boston-bound service with boardings within the PMT study area are as follows (see also Figure C-6):

- Big W Trans, Inc. (from Northborough)
- Bloom Bus Lines (from Taunton)
- Brush Hill Transportation (from Milford)
- Carey Bus Lines (from Whitman)
- C&J Trailways (from Durham, NH, via Newburyport)
- Gulbankian's Bus Lines (from Hudson)
- Greyhound Lines (from Portland, ME via Newburyport)
- Hudson Bus Lines (from Peabody; Lexington; Stoneham)
- Interstate Coach (from Middleborough)
- Peter Pan Bus Lines (from Westborough; Framingham; Worcester)
- Plymouth & Brockton Street Railway Co. (from Brockton; Plymouth Center*; Scituate; Pembroke Center; S. Duxbury; Hyannis (serving Plymouth).
- Timberlane Coach (from Amesbury; Newburyport; Haverhill)
- Trombly Commuter Lines (from North Andover)
- Yankee Line (from Littleton)

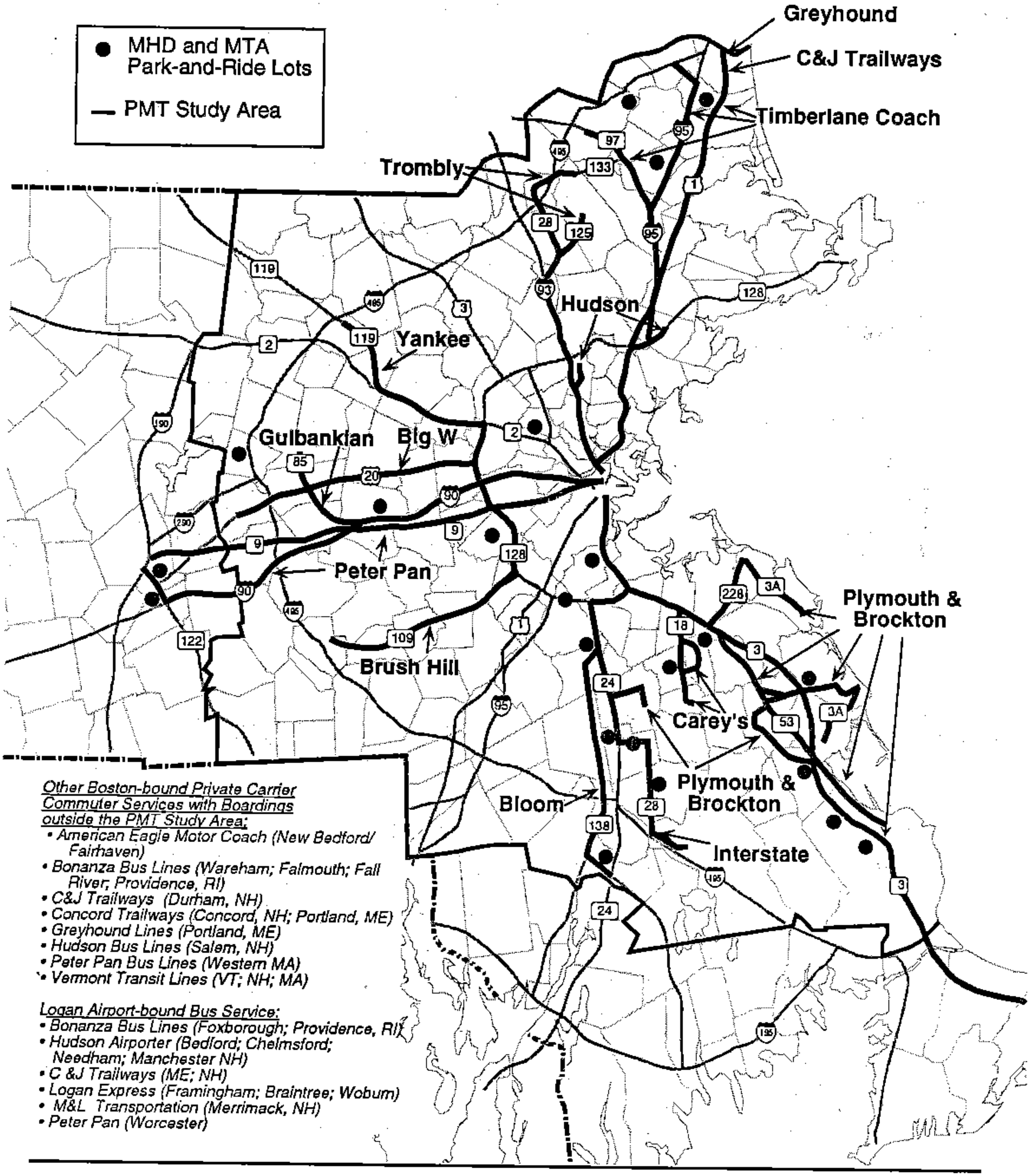
Table C-4
FY 1992 Suburban Bus Service

Bedford	**Lynn**
•Local fixed route & demand response service •Shoppers service •One 12 passenger van	•Intra-town fixed route service shoppers service •One full size bus
Beverly	**Mission Hill**
•Local fixed route •Business district shoppers service •One 25 passenger bus	•Local fixed route service •Commuter link to MBTA Orange & Green Lines •Medical area service •One mini-bus
Burlington	**Natick**
•Local fixed route service •Commuter link to MBTA bus service at Burlington Mall •Shoppers service •Three mini-buses	•Intra-town fixed route and demand response service •Commuter link to MBTA commuter rail service & Peter Pan Bus Service •Commuter bus & Framingham Shoppers World Mall •Shoppers service •Two mini-buses
Dedham	**Norwood**
•Local fixed route service •Commuter link to MBTA bus service at Dedham Mall •Shoppers service •One full size bus	•Elderly & handicapped transport service •Intra-town demand response service •Taxi cabs & handicapped accessible vans
Framingham	**Lexington**
•Intra-town fixed route service •Commuter link to MBTA bus, commuter rail & Natick Suburban •Bus service at Shoppers World Mall •One full size bus & three mini-buses	•Intra-town fixed route service •Shoppers service •Four mini-buses

Operators providing inter-suburban and other services, within the study area, are as follows:

- Andre Coachlines (between Hull and Hingham)
- Hudson Bus Lines (between Canton and Mattapan; in Medford: Fulton Street to Meadow Glen Mall)
- Town of Framingham/Big W (between Hopkinton and Framingham; between Milford and Framingham)
- Michaud Bus Lines (between Peabody and Salem)
- Paul Revere Transportation (between Winthrop and East Boston)
- Plymouth & Brockton Street Railway Co (between Marshfield and Braintree)
- Reliable Bus Lines (Charlestown Navy Yard)

Figure C-6
Boston - Bound Private Carrier Bus Services Contained in The PMT Study Area



Other Boston-bound Private Carrier Commuter Services with Boardings outside the PMT Study Area:

- *American Eagle Motor Coach (New Bedford/ Fairhaven)*
- *Bonanza Bus Lines (Wareham; Falmouth; Fall River; Providence, RI)*
- *C&J Trailways (Durham, NH)*
- *Concord Trailways (Concord, NH; Portland, ME)*
- *Greyhound Lines (Portland, ME)*
- *Hudson Bus Lines (Salem, NH)*
- *Peter Pan Bus Lines (Western MA)*
- *Vermont Transit Lines (VT; NH; MA)*

Logan Airport-bound Bus Service:

- *Bonanza Bus Lines (Foxborough; Providence, RI)*
- *Hudson Airporter (Bedford; Chelmsford; Needham; Manchester NH)*
- *C &J Trailways (ME; NH)*
- *Logan Express (Framingham; Braintree; Woburn)*
- *M&L Transportation (Merrimack, NH)*
- *Peter Pan (Worcester)*

In FY 1991, daily ridership on those state subsidized routes listed above averaged 6,000 trips. Other subsidized bus service serving communities outside the study area include American Eagle Motor Coach (from New Bedford to Boston, Express) and Wilson Bus Lines (between Gardner and Fitchburg).

Caravan Service

CARAVAN for Commuters, Inc., Massachusetts' private non-profit commuter services company, provides comprehensive transportation services to commuters and their employers which facilitate transit and shared ride transportation alternatives to drive alone commuting. CARAVAN serves a client base of close to 1,000 corporations to create transportation programs for employers, developers, and communities.

In addition, it works with public and private decision-makers forming Transportation Management Associations (TMAs) to improve commuter mobility on an areawide basis. TMAs already formed include the Route 128 Transportation Council (Waltham area), CommuteWorks (Longwood Medical Area, Boston), the Back Bay TMA, and the Interinstitutional TMA (South End Medical Area, Boston). Those currently in the formation stages include the North Suburban TMA (Route 128 between routes 2A and 129), the 495 West TMA (Route 9, Marlborough) and the MetroWest TMA (Framingham and Natick).

CARAVAN also forms vanpools, recruits riders, and administers company-sponsored, owner-operator, and multi-vendor vanpool programs. Current ridership on 215 vans totals 6,020 trips per day, with an average daily round trip mileage of 85 miles. For commuters without access to transportation services at the work site, CARAVAN provides commute planning assistance directly with its statewide commuter information line.

Paratransit

The MBTA provides three specialized accessible service programs: The RIDE, wheelchair-lift bus routes, and Call-a-Lift Bus. In addition, there are a number of accessible services operated by cities and towns, Councils on Aging, and charitable operations.

The RIDE service is a paratransit program that provides transportation to people who cannot use general public transportation because of disabilities. The RIDE operates lift-equipped vans in 44 communities within the MBTA district, a service area that exceeds 486 square miles organized into five separate geographic areas (see Figure C-7). In FY 1991, approximately 1,100 trips were made on The RIDE each day. The Wheelchair-Lift program provides only lift-equipped buses on certain regularly scheduled bus routes. These routes are called "Lift Bus Routes" and are identified on schedule cards with the international symbol for accessibility. The Call-a-Lift Bus program provides lift-equipped buses upon request on routes where no scheduled buses are wheelchair lift equipped (except trackless trolleys).

Overall, The RIDE program consists of a fleet of 221 vehicles, 116 of which are owned by the MBTA. There are currently seven contractors providing service to over 17,000 registered RIDE customers: DAVE Transportation Services, Veterans Transportation Services and Kit Clark Senior House in the Core area; Share-A-Ride in the Northwest area; Thomson

Figure C-8

Rapid Transit Park-and-Ride Facility Capacity, by Station

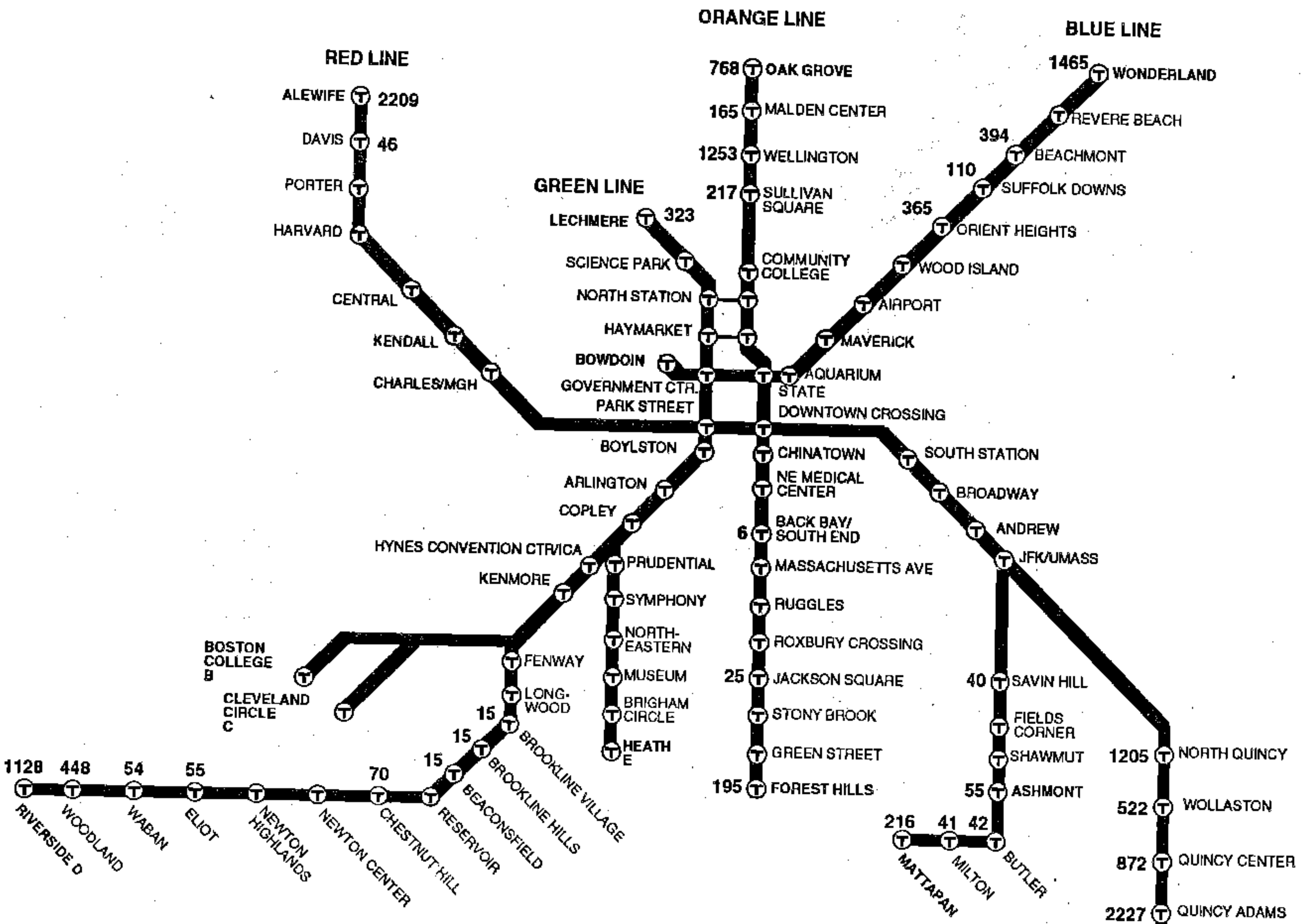
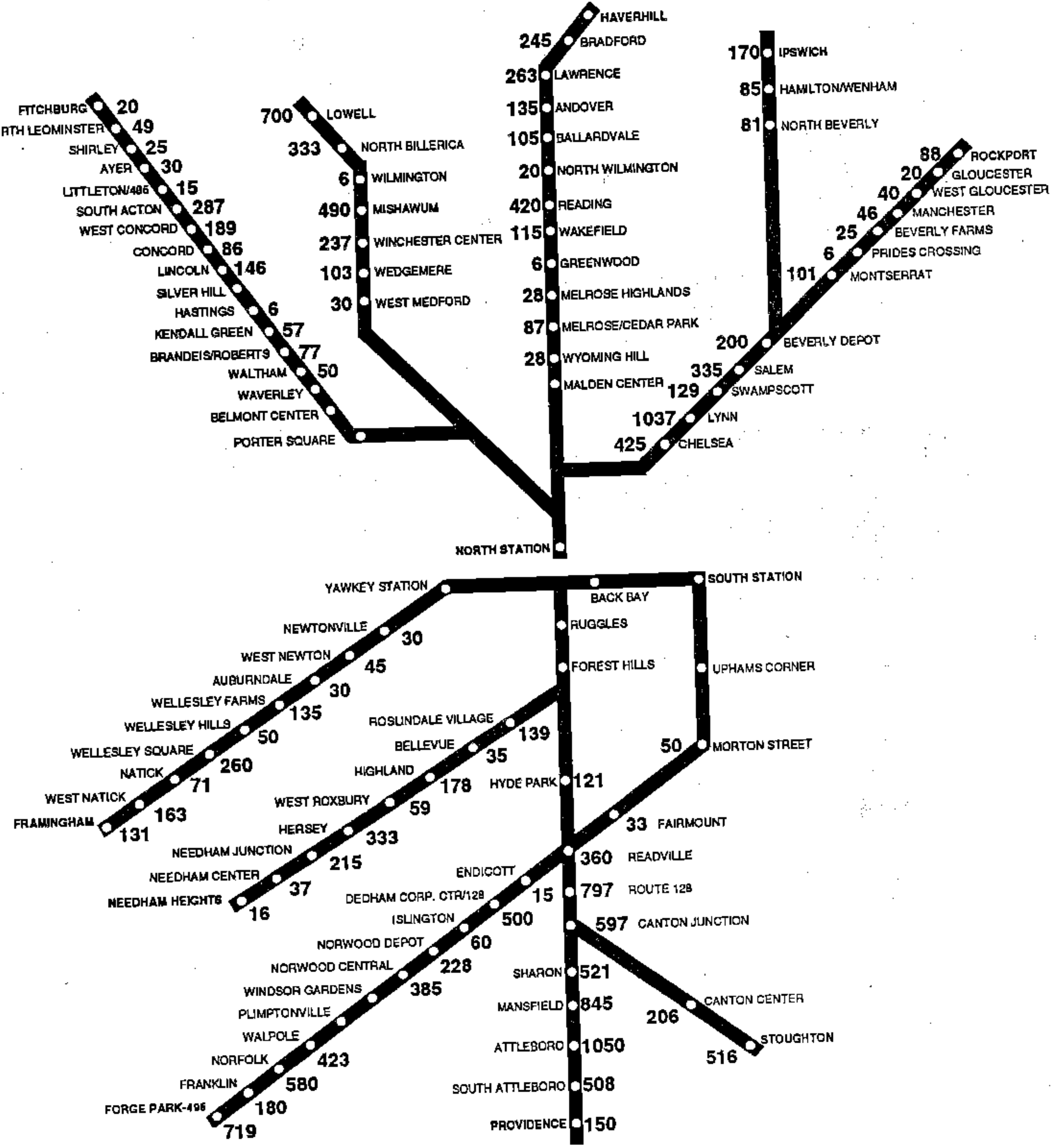


Figure C-9
Commuter Rail Park-and-Ride Facility Capacity, by Station



weekend trains and during non-peak hours on weekdays (outbound until 3:00 pm and inbound from 9:30 am to 6:30 pm).

Bicycle Parking at Transit Stations

Bicycle racks have been installed at both rapid transit and commuter rail stations throughout the MBTA system. As of April 1991, racks had been installed at more than 50 percent of the Red Line and Orange Line stops, 35 percent of the Green Line stops, 25 percent of the Blue Line stops, and 32 percent of commuter rail stations. The MBTA has also conducted a preliminary test of bicycle lockers at Wollaston Station on the Red Line.

Bicycle Commuting by Boat

Three commuter boat carriers, i.e. Boston Harbor Commuter Service, Mass. Bay Lines and Bay State Cruises operating service between the South Shore and downtown Boston, accept bicycles on a space-available basis at no extra charge.

Logan Airport Bicycle Access

Since 1989, Massport has provided a taped message for bicyclists as part of its 1-800-23-LOGAN information program. Bicycles are permitted on both airport shuttle buses and the Logan Express buses from Framingham and Braintree. Parking is available at the Maverick Station gate area.

Appendix D
Progress Since the Last PMT

The 1978 Program for Mass Transportation contained two categories of capital improvements, one for plant and vehicle improvements and the other for service expansion. The first category covered such items as electric power sources for the system, track renovations, improvements in the signaling system and communications, maintenance and storage facilities, bus and rapid transit vehicles, station modernization, parking capacity expansion, and accessibility improvement projects. The chapter on new service projects listed fifteen proposals, including improvements to all of the transit lines and three new routes.

Since 1978, much of the capital program has been implemented, or is in the process of being implemented. These improvements are discussed below, presented by mode and also organized by transportation corridor. Following this section is a status report on the PMT projects which have not been implemented to date.

Completed Projects

Rapid Transit and Light Rail

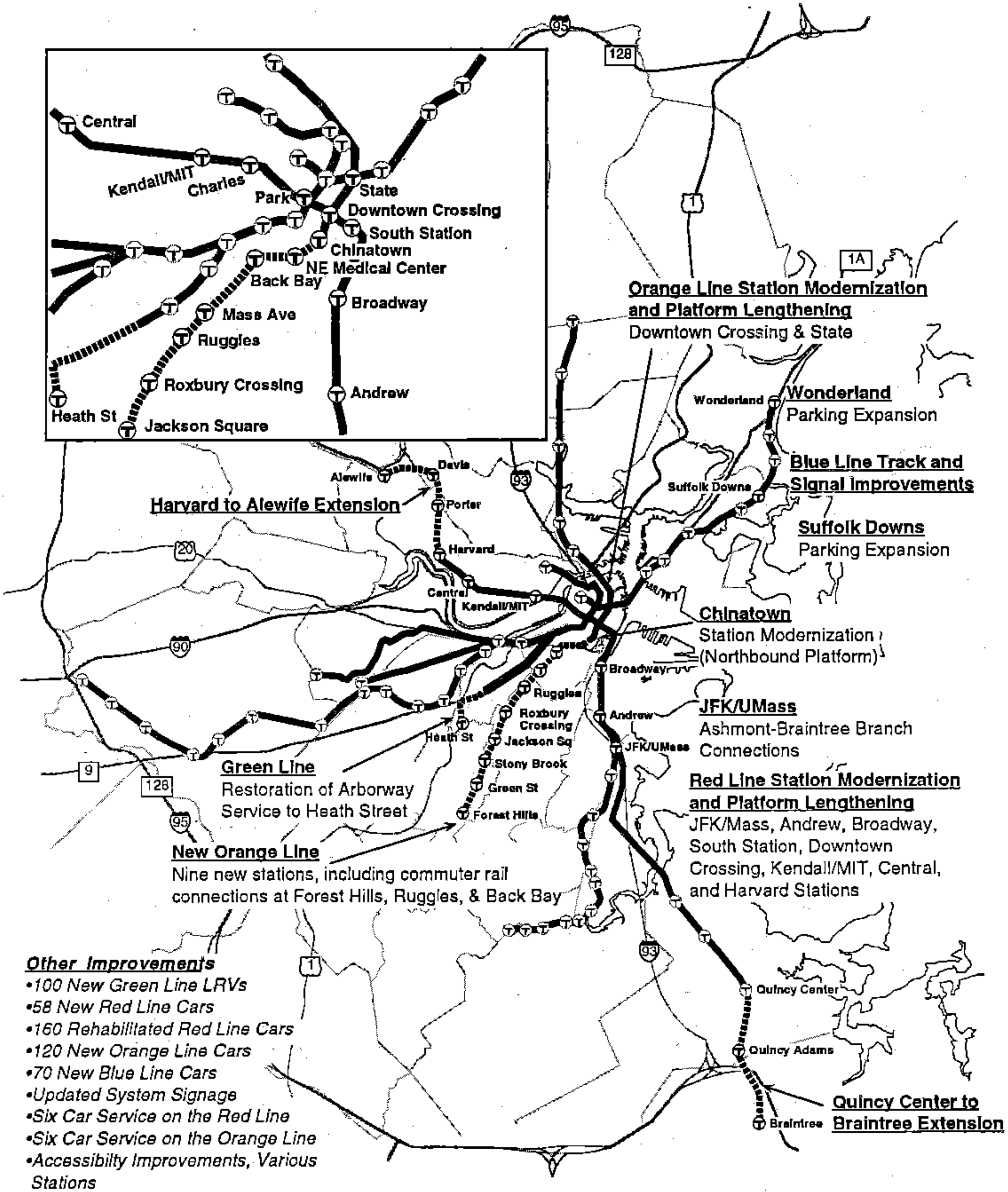
System wide improvements to rapid transit and light rail have included investment in existing infrastructure, improvements to vent shafts, tunnels, signaling systems, emergency exits and electrification. Line specific improvements over the past 12 years have increased capacity and ridership. These improvements are shown in Figure D-1.

Red Line

Since 1978, the Red Line has been extended at both ends: from Harvard to Alewife at the Cambridge end, and before that, from Quincy Center to Braintree at the southern end. The Alewife extension added three new stations: Porter Square in Cambridge, Davis Square in Somerville, and Alewife in North Cambridge. Alewife Station has 2,209 parking spaces. The Braintree extension added two new stations: Quincy Adams and Braintree. These two stations have 2,227 and 1,228 parking spaces, respectively.

In addition, Harvard, Central, Kendall/MIT, Charles/MGH, Park Street, Downtown Crossing, South Station, Broadway, Andrew (construction in progress) and

Figure D-1
Rapid Transit Improvements Since 1978



Orange Line Station Modernization and Platform Lengthening
Downtown Crossing & State

Wonderland
Parking Expansion

Blue Line Track and Signal Improvements

Suffolk Downs
Parking Expansion

Harvard to Alewife Extension

Chinatown
Station Modernization
(Northbound Platform)

JFK/UMass
Ashmont-Braintree Branch Connections

Red Line Station Modernization and Platform Lengthening
JFK/Mass, Andrew, Broadway, South Station, Downtown Crossing, Kendall/MIT, Central, and Harvard Stations

Green Line
Restoration of Arborway Service to Heath Street

New Orange Line
Nine new stations, including commuter rail connections at Forest Hills, Ruggles, & Back Bay

Quincy Center to Braintree Extension

Other Improvements
- *100 New Green Line LRVs*
- *58 New Red Line Cars*
- *160 Rehabilitated Red Line Cars*
- *120 New Orange Line Cars*
- *70 New Blue Line Cars*
- *Updated System Signage*
- *Six Car Service on the Red Line*
- *Six Car Service on the Orange Line*
- *Accessibilty Improvements, Various Stations*

JFK/UMass stations were modernized and/or had their platforms lengthened. A connection between the Ashmont and Braintree branches was built at JFK/UMass. Fourteen out of 22 stations were made accessible.

A total of 145 new Red Line cars have purchased, and 160 Red Line cars were rehabilitated. This has allowed for the operation of six-car trains (up from four), which increased capacity and reduced crowding.

Orange Line

The largest Orange Line improvement was the relocation of service between Chinatown and Forest Hills to the Southwest corridor. This included the construction of nine new stations, including commuter rail connections at Forest Hills, Ruggles and Back Bay. Chinatown, Downtown Crossing, and State stations were modernized and platforms lengthened. Chinatown Station improvements also included the reconstruction of the northbound platform and a new station entrance. Twelve out of 19 stations were made accessible, and accessibility improvements at two additional stations are currently in progress.

A total of 120 new Orange Line cars were purchased. With the new cars, plus the platform lengthenings, six-car trains are now operated.

Blue Line

Improvements on the Blue Line have included track and signal improvements and the acquisition of 70 new Blue Line cars. Station and parking improvements at Suffolk Downs and Wonderland stations added 110 and 420 new parking spaces respectively. Suffolk Downs was made fully accessible and the outbound platform at State was made partially accessible.

Preliminary work is now underway in preparation of a major reconstruction of Blue Line stations to lengthen platforms to expand capacity and to make them accessible.

Green Line

Light rail improvements included upgrading of the track, signal and cable systems, and the acquisition of 100 new Green Line vehicles.

Bus and Trackless Trolley

Improvements to the MBTA bus system involved ongoing bus fleet modernization, a new bus garage in Lynn, station improvements at Haymarket, and a new terminal at Arlington Heights (with 194 park-and-ride spaces). A new bus terminal was constructed at the site of the old Dudley Orange Line station in Dudley Square in Roxbury. Two hundred buses were retrofitted with air conditioning to improve passenger comfort.

Service changes involved improved service between the South End Medical Area, the Longwood Medical Area, Allston-Brighton and Cambridge. In addition, local bus routes that provide feeder connections to the new stations on the Red Line and Orange Line were restructured.

In the early 1980s, the MBTA renewed its Suburban Bus Program which currently provides funding to ten communities for local bus service in areas not served by MBTA local bus routes. The state began providing subsidies to private bus carriers which operate radial services to downtown Boston, feeder services to fixed rail transit stations, or local "suburban bus" services.

Commuter Rail

Improvements to the commuter rail system have both been in response to, and further encouraged, the large ridership increases of the 1980s. System wide improvements included the purchase of 44 locomotives, approximately 200 new single-level commuter rail coaches and 75 bi-level coaches. In addition, track, platform and accessibility improvements at North Station, South Station and Back Bay Station were completed during this period. Specific improvements by line include (see also Figure D-2):

Rockport/Ipswich Line

Station improvements included parking expansion at Lynn (800 new spaces) and Salem (430 spaces) stations, a new station in Chelsea (425 spaces) and accessibility improvements to Swampscott Station. Bridge reconstruction projects included the Beverly-Salem Bridge, Draw 7 replacement over the Mystic River and the North Station Trestle. Except for Rockport, Prides Crossing and Chelsea stations, all stations on this line are now accessible.

Haverhill Line

Commuter rail service was restored from Reading to Haverhill with new station stops in Wilmington, Andover, Lawrence and Haverhill. Subsequent station improvements include parking expansion at Reading Depot (40 new spaces), Ballardvale (105 new spaces), Andover (18 new spaces), Bradford (200 spaces), and Lawrence (100 new spaces). Reading Depot was made accessible, and Bradford, Lawrence, Andover and Ballardvale are under construction for accessibility.

Lowell Line

Improvements include the opening of a new station at Mishawum in September, 1984 (286 new spaces). Other parking expansions included North Billerica (110 new spaces) and the development of a transportation center at a new Lowell station (700 spaces). Lowell and Mishawum stations were made accessible.

Fitchburg/Gardner Line

Parking and accessibility improvements to Brandeis-Roberts Station in Waltham added 77 new parking spaces. West Concord and Porter stations were also made accessible.

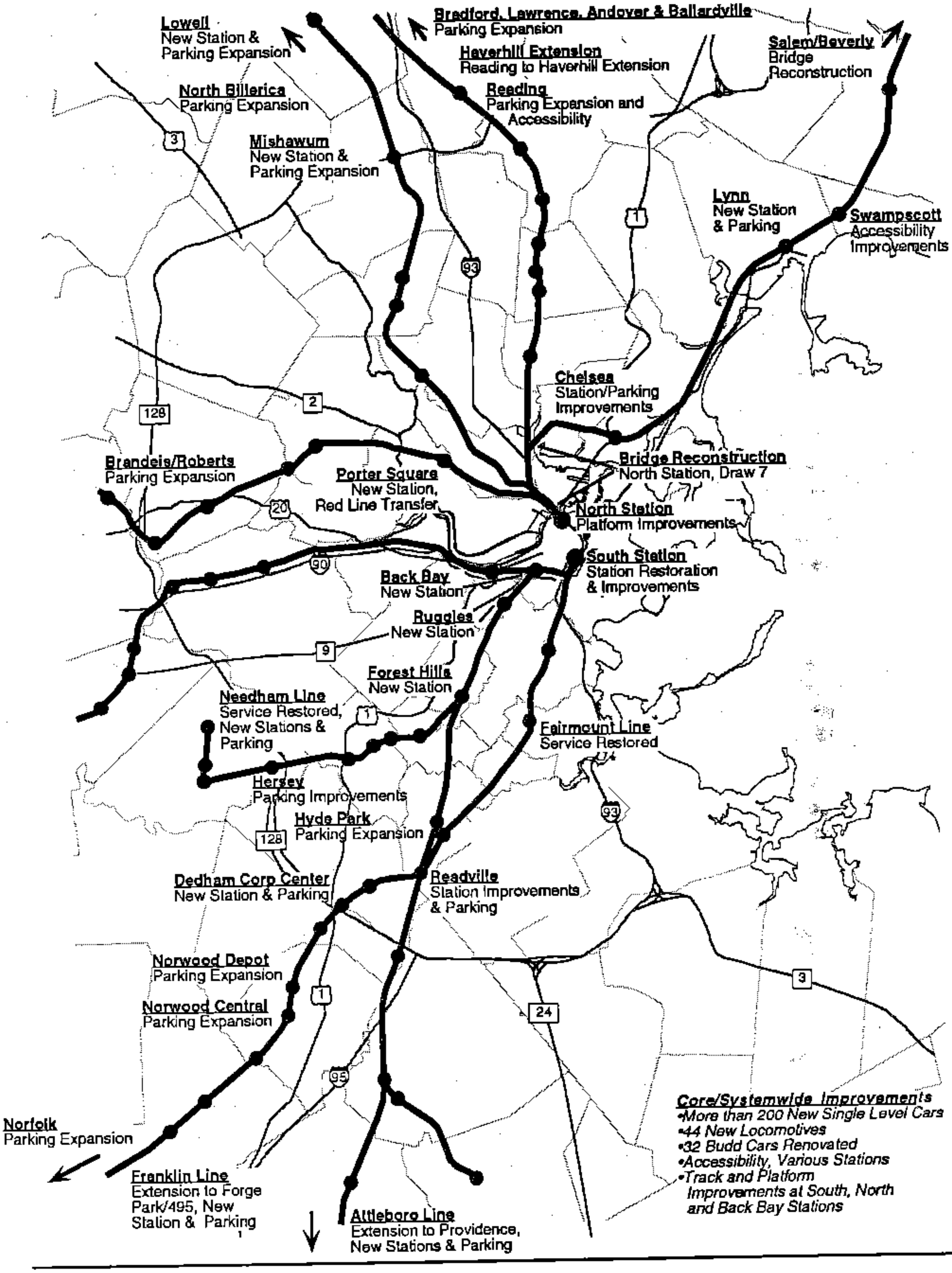
Needham Line

Rail service was restored and upgraded to Needham, West Roxbury and Roslindale. All eight stations are fully accessible and provide a total of 860 parking spaces. Recently 150 parking spaces were added at Hersey Station in Needham.

Franklin Line

Improvements include an extension from Franklin Center to Forge Park in Franklin with a 719-space park-and-ride facility. A new station was also constructed in Dedham (Dedham Corporate Center) with 500 parking spaces. Other station improvements include parking expansions at Readville (200 new spaces) and Norwood Depot (85 new spaces). Those stations made accessible include Forge

Figure D-2
Commuter Rail Improvements Since 1979



Core/Systemwide Improvements
- *More than 200 New Single Level Cars*
- *44 New Locomotives*
- *32 Budd Cars Renovated*
- *Accessibility, Various Stations*
- *Track and Platform Improvements at South, North and Back Bay Stations*

Park/495, Norfolk, Norwood Central, Norwood Depot, Dedham Corporate Center and Readville.

Attleboro/Stoughton Line

Improvements include Main Line work between Providence, RI and Boston with new stations in Providence (150 parking spaces provided by the state of Rhode Island) and South Attleboro (500 spaces). Southwest corridor improvements include the relocation of tracks from an embankment to below-ground, with new stations at Forest Hills and Ruggles. Subsequent improvements to Hyde Park station added 61 spaces. Stations made accessible include Providence, South Attleboro, Attleboro, Mansfield, Stoughton, Canton Center and Hyde Park.

Fairmount Line

Local commuter rail service through Hyde Park, Mattapan and Dorchester was restored. Station stops include Fairmount (30 spaces), Morton Street (50 spaces) and Uphams Corner.

Commuter Boat

Commuter boat service between the Hingham Shipyard in Hingham and Rowe's Wharf in Boston was expanded in 1984 as mitigation for the reconstruction of the Southeast Expressway. Improvements to Rowe's Wharf have made this terminal a focal point for other water transportation services such as the shuttle service to Logan Airport. Other boat services that have been implemented include a Charlestown Navy Yard to Long Wharf route, and a route from Nantasket Pier in Hull (temporarily suspended as of December 24, 1991).

Transit Improvements Currently Underway

Rapid Transit and Light Rail

Red Line

Andrew Station is being modernized and Quincy Center Station is being made accessible.

Blue Line

Improvements are underway to upgrade the entire Blue line. In addition to modernizing stations, this project will also make all stations accessible and lengthen platforms to accommodate six-car trains.

The carhouse at Orient Heights Station is being upgraded for the maintenance and storage of Blue Line cars.

Green Line

New accessible Green Line vehicles are being designed and all Green Line stations will be modernized to include accessibility. Electronic fareboxes are being procured for Green Line vehicles. Yard improvements to Riverside Station and restoration of

Arborway E-Line service from Heath Street are underway. The Green Line at North Station will be relocated to provide a cross-platform connection to the Orange Line.

Figure D-3 presents a map of rapid transit projects currently underway.

Bus and Trackless Trolley

All MBTA buses are being equipped with electronic fareboxes, and a new bus terminal is being constructed at South Station.

Commuter Rail

As part of the New Boston Garden, commuter rail facilities are being upgraded. Ongoing improvements include relocation and lengthening of commuter rail platforms. The MBTA's bridge reconstruction program is also addressing railroad bridge needs system wide. Improvements underway by line are as follows (see Figure D-4):

Haverhill Line
Improvements to Haverhill Station will include a park-and-ride facility to contain 300 spaces.

Fitchburg/Gardner Line
Improvements to Littleton/495 Station will add 300 parking spaces to an existing supply of 15. Improvements to Fitchburg Station will add 100 spaces to an existing supply of 20.

Framingham Line
Station improvements to Auburndale, Newtonville and West Newton stations will accommodate 2 track operations.

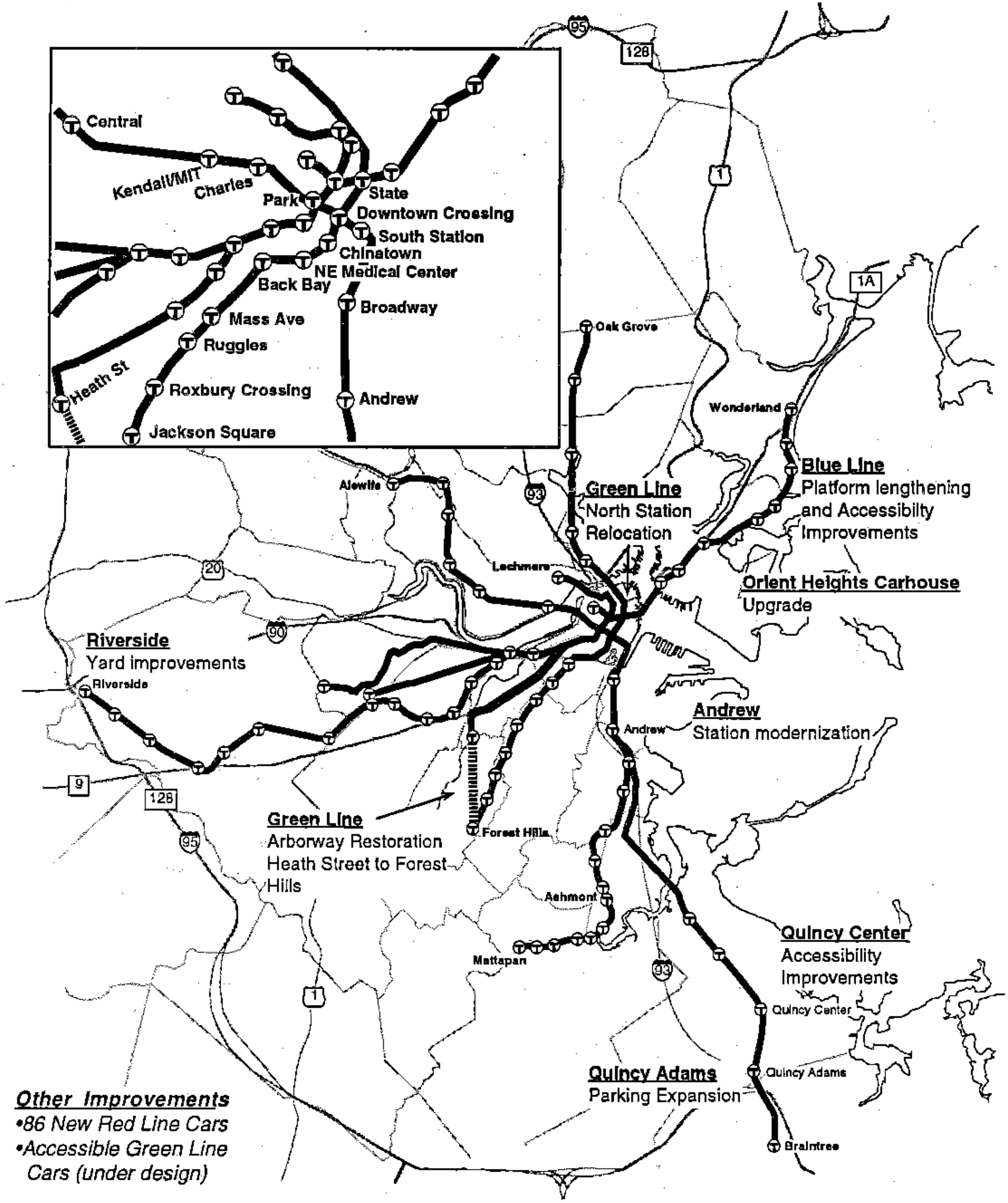
Franklin Line
Design of an extension from Forge Park/495 to Bellingham is underway. Construction will include a new station with a 500-space park-and-ride facility and a nighttime layover facility.

Attleboro/Stoughton Line
Parking improvements at Canton Junction and Route 128 stations will add 310 and 1,400 parking spaces respectively. Improvements to Northeast Corridor right-of-way will improve travel time between Boston and New York.

Commuter Boat

Improvements are underway at the Hingham Shipyard to add 800 new spaces to an existing supply of 1,350.

Figure D-3
Rapid Transit Improvements Underway



Green Line
North Station
Relocation

Blue Line
Platform lengthening
and Accessibilty
Improvements

Orient Heights Carhouse
Upgrade

Riverside
Yard improvements

Andrew
Station modernization

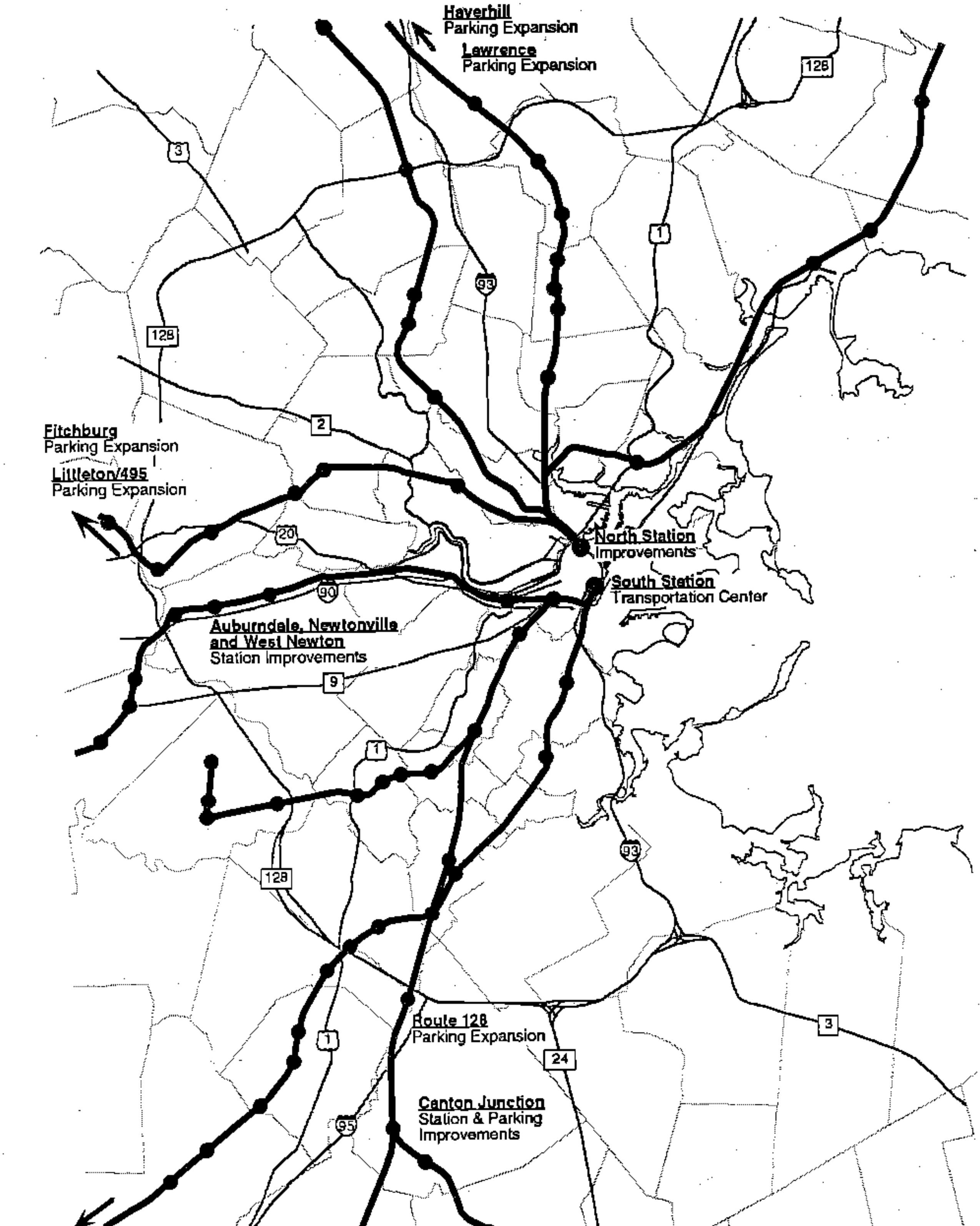
Green Line
Arborway Restoration
Heath Street to Forest
Hills

Quincy Center
Accessibility
Improvements

Quincy Adams
Parking Expansion

Other Improvements
- *86 New Red Line Cars*
- *Accessible Green Line Cars (under design)*

Figure D-4
Commuter Rail Improvements Underway



Status of Projects Not Implemented to Date

Eleven "new service" projects included in the 1978 PMT Update have not been implemented to date. These are as follows:

Blue Line Extension to Lynn

As examined in the 1978 PMT, this project consisted of an extension of the Blue Line from Wonderland Station in Revere along the Ipswich/Rockport commuter rail right-of-way, with new stations constructed in West Lynn and Central Square. A connection to commuter rail would have been available at the Central Square Station in downtown Lynn. The purpose of the project was to improve transit service both to and from the city of Lynn, an old urban center in need of revitalization.

A draft Environmental Impact Statement was prepared and reviewed by the Federal Transit Administration (FTA), formerly the Urban Mass Transportation Administration, at the time of the last PMT update. Project implementation was deferred due to funding limitations.

For the 1993 PMT, an extension was examined from Wonderland along the Narrow Gauge right-of-way with three stations: Point of Pines, West Lynn, and Lynn. As described in Chapter 9, this extension is recommended as an Additional Expansion Long-Range Tier 2 project.

Orange Line North Extension to Route 128

This project was an extension of the Orange Line from Oak Grove along the Haverhill commuter rail line right-of-way with stations at approximately the same locations as the present commuter rail line in Melrose and Wakefield: Wyoming Hill, Melrose, Melrose Highlands, Greenwood and Wakefield. An additional station, the proposed terminus, would be located at Route 128. Three vertical alignments alternatives were studied. These were: (1) at grade, (2) partially grade separated, and (3) fully grade separated. Grade separation alignments would have resulted in reduced impact on local traffic, but significantly higher capital costs.

The project was originally conceived to both reduce congestion at the inner Orange Line stations and attract new riders to the MBTA system. The Orange Line extension was estimated to save 9 minutes of travel time over an upgraded commuter rail.

Extensive environmental review work done in 1975 revealed strong concerns about potential traffic congestion and unwanted new development. Because of these concerns and severe budget constraints, the project was not pursued. Since 1978, commuter rail improvements on the Haverhill Line have enhanced service in this corridor. Because of the success of the upgraded commuter rail service, the Orange Line extension to Route 128 was not reexamined in the 1993 PMT.

Red Line Northwest Extension to Route 128 (Phase 2)

This project involved an extension of rapid transit service from Alewife Station to Route 128 on the former Lexington branch railroad right-of-way. Stations were proposed for Arlington Center, Arlington Heights, Lexington Center and Route 128. The project was originally conceived when Red Line service terminated at Harvard Square. Phase 1, the extension of Red Line service from Harvard to Alewife Station, opened in the mid 1980s.

This project was reexamined in the 1993 PMT. As detailed in Appendix G, it would attract relatively few new transit trips and be very expensive to construct. As a result, it is not included in the recommended program.

Green Line Extension to Tufts College in Medford

This project would extend the Green Line from Lechmere Station in East Cambridge through Somerville to a point near Tufts College in Medford. Lechmere Station would be relocated to the east side of the O'Brien Highway. Stations are proposed at Washington Street, McGrath Highway, School Street, Lowell Street, Ball Square (Broadway) and Tufts University. Alternative terminal locations considered included Ball Square and Washington Street in Somerville.

This project was originally conceived to provide a one-seat, one-fare rapid transit service to Somerville, a city of high population density, low auto ownership, lower than average incomes and a high percentage of elderly. Before Red Line stations at Porter and Davis squares opened, residents had no choice but to take a bus over congested city streets to rapid transit stations in Cambridge and Charlestown.

This project was reexamined in the PMT and, as described in Chapter 8 and Appendix G, would provide significant benefits. It is included in the 1993 PMT as a recommended SIP and CA/T Mitigation project.

Green Line Extension to Brighton

This project would have restored Green Line service from Kenmore Square as far as Oak Square in Brighton, short of a full restoration of the old A Line to Watertown Square. LRVs would have operated on existing tracks in the street along Washington and Cambridge streets between Oak and Union squares. Tracks would have been rebuilt in a mid-street reservation between Union Square and Packard's Corner, along Brighton Avenue, to where it meets the B Line on Commonwealth Avenue. The existing tunnel would have been used between Kenmore Square and Park Street. This line would have replaced existing MBTA bus service (Route #57) that terminates at Kenmore Station.

This project is designed to provide a one seat ride to patrons from Brighton and Allston who wish to use the Green Line service to reach downtown destinations.

This project was reexamined in the 1993 PMT. As described in Appendix G, it would attract relatively few new transit trips and be relatively expensive to reinstitute service. It is not included in the recommended program.

Washington Street Replacement Service

Washington Street Replacement Service consists of the implementation of trolley bus or light rail service on Washington Street between Dudley Square in Roxbury and Downtown Crossing in downtown Boston. (Earlier planning had been for trolley bus service, however EOTC and the MBTA are now reconsidering light rail.) The service is intended to replace that which was previously provided by the elevated Orange Line, which was relocated to the southwest corridor. The project could also include operation into Boylston Station and connection to the South Boston Piers Transitway. This project is being funded with state funds, and as a result, only the state environmental process is required. The figures presented herein are derived from figures in the project's ENF for a trolley bus service (with the reconsideration of light rail, these figures may change).

This project was considered a "base case" project and is included in the 1993 PMT as a recommended SIP and CA/T Mitigation project.

Rail Service to Brockton

This project was originally conceived to provide better service to patrons in the Brockton area. The project would have restored rail service from Brockton over the existing railroad right-of-way between Brockton and Quincy. Service options included 1) an extension of the Red Line from South Braintree, 2) a separate commuter rail line to South Station, 3) a railroad shuttle to the Red Line, and 4) a special lightweight diesel rail car operating on a separate right-of-way beyond Quincy and sharing Red Line tracks north of Quincy.

The MBTA is currently in the process of restoring service along the Middleborough, Plymouth and Greenbush branches of the former Old Colony railroad. Three stations in Brockton will be constructed on the Middleborough Line.

Circumferential Transit

This project was originally conceived to provide new or improved service in a circumferential corridor around the fringe of the Boston Central Business District, connecting the Sullivan Square area of Charlestown, East Cambridge, MIT, Boston University, Northeastern University and the proposed Roxbury replacement service. Additional service was considered to connect to either the Columbia Point or South Boston areas. The study of service to South Boston was later separated from the Circumferential Study to become the South Boston Piers Feasibility Study. Transfer stations would be located at intersections with rapid transit and light rail lines. The 1978 PMT found that a circumferential transit line would result in significant user time savings and would clear much of the peak period congestion at the downtown transfer stations. Also, the line would provide an important new link among the major educational, medical and cultural institutions along this corridor, as well as for the new industrial areas being developed in Somerville and Cambridge.

Since 1978, a number of ongoing planning studies have been conducted to identify and analyze technology alternatives. Most recently, the MBTA has undertaken a "Crosstown Transit Feasibility Study" to further examine bus options. In addition, the City of Boston is conducting its own "Crosstown Transit" study, and the Boston Society of Architects has recently begun to examine the concept of a "New Urban Ring."

The PMT analysis included an examination of two light rail alternatives, one of which would run from Sullivan Square to Ruggles ("Core LRT"), and one that would run from Logan Airport to JFK/UMass ("Full LRT"). These alternatives are described in Chapter 9 and Appendix G.

In summary, the 1993 PMT analysis has confirmed that there is a significant demand for improved circumferential transit services. However, a large number of issues remain as to alignment, funding, and technology, and additional examination is still needed. Inner Circumferential Transit is included in the 1993 PMT as an Additional Expansion Long-Range Tier 3 project.

Brookline Village Connector

This project would have consisted of the construction of a short piece of new track from the Brookline Village Station, on the Riverside Branch of the Green Line, to E Line on Huntington Avenue. This project would have allowed for the operation of service from Brookline Village to Huntington Avenue, with is not served by the Riverside Branch. The service would have enabled transit users boarding in Newton and Brookline to access the hospitals, museums and educational institutions without having to switch trains at Copley.

Since 1978, there has been a considerable amount of new construction in the Brookline Village area, which would make construction of this connection difficult. As a result, this connection was not reexamined in the 1993 PMT.

North Station-South Station Connector

This project, as examined in the 1978 PMT, would have consisted of either a subsurface or surface rail link between North and South stations, as part of the Central Artery Third Harbor Tunnel project. The new tunnel would run parallel to the depressed artery and would include underground platforms at North Station, at State Street in Financial District and at South Station. Intercity and commuter trains would enter the tunnel by switching from existing tracks on the approach to North and South Stations. The link would improve the downtown distribution characteristics of the commuter rail and provide through intercity train service from Maine and the North Shore to points south of Boston.

The construction of a Rail Link in the Central Artery corridor was recently found to be feasible by the Central Artery Rail Link Task Force.[1] The Rail Link, as it is currently envisioned, is described in Chapter 9 and Appendix G. The Rail Link is included in the 1993 as an Additional Expansion Long-Range Tier 1 Project.

Bowdoin-Charles Connector

This project would extend the Blue Line four-tenths of a mile from its downtown terminal at Bowdoin Street to Charles Street on the Red Line. The new line would be located in a tunnel underneath Cambridge Street with a new below ground Blue Line station at Charles Street. Blue line trains would reverse direction at Charles Street through the use of tail tracks and switches.

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[1] "Building for an Intermodal Future: The North-South Rail Link," EOTC, May 1993.

All rapid transit lines except for the Blue and Red lines intersect each other in the downtown Boston area. This project would provide that connection. This would improve transit accessibility between the communities of the inner Northwest corridor served by the Red line and the communities of the North Shore served by the Blue Line. Travel time savings would be realized to those people who now make two transfers and to those who walk an extra distance to avoid the double transfer.

The Bowdoin-Charles Connector is included in the 1993 PMT as a SIP and CA/T Mitigation Project.

Appendix E
Demand Forecasting Process

When demand forecasting for the PMT began in September 1992, the best available projections of population, employment, and travel were for the year 2010. Therefore, initial ridership estimates were produced using those projections and the then-current CTPS regional travel model. Concurrently, CTPS was in the process of updating its model set using newly collected travel data and new MAPC projections of 2020 population and employment. This effort led to the development of an "Interim Model" set, which was used to analyze highway and transit strategies for the Transportation Plan. So that the PMT and Transportation Plan would be consistent, a decision was made to update the PMT projections to reflect the most recent 2020 projections, and improvements in travel projections included in the Interim Model.

This appendix describes the demand forecasting process, and the method used to update the PMT ridership estimates from 2010 to 2020. This includes:

- An overview of the nature and role of the Boston Metropolitan Planning Organization's regional model set.
- A discussion of how the model set was recently updated for use in the draft Transportation Plan.
- A description of the steps in the model set.
- Information about how the model set will be further improved in the future.
- A description of the technical procedure used to update the 2010 ridership forecasts to 2020.

Overview of the Regional Model

A regional land use/transportation model set is composed of several models that together simulate intra-regional passenger transportation supply and demand for the current and future years. Supply enters the model set in the form of a computerized representation of the region's highway and transit systems. All express highways and major arterials, most minor arterials and many local roadways are included. All transit lines, both public and private, are included. Demand enters the model in the form of weekday trips that are generated from population, employment and land use.

A regional model set is used to forecast changes in regional travel patterns that would result from certain actions. Historically, those actions have focused on major new or widened roadways and new or extended transit lines. Also, regional models have been used to estimate the systemwide travel effects of changes in such things as transit fares, parking price or supply and fuel prices. Recently, regional models have come to be used in forecasting the impacts of transportation system changes on air quality.

Travel forecasting models used at a regional level are appropriate for developing regional transportation plans, but are not necessarily the best tool in all planning situations. Precise and accurate forecasts of roadway traffic volumes and transit line volumes are often obtained by using these same models, but at a corridor or subarea level, where supply and demand variables can be represented with more detail and where relationships in the models can be calibrated more precisely. Even more fine-grained forecasts, such as those of intersection levels-of-service must be obtained from operations-level traffic forecasting models.

The Intermodal Surface Transportation Efficiency Act of 1991 and the Clean Air Act Amendments of 1990 have placed new demands on travel forecasting models and on those who develop and use them. These models are being relied on for guidance in how transportation investments inter-relate with land use patterns, air quality and livable communities. Neither this region's nor any other region's models can provide all of the guidance being sought, but the models used in the PMT were recently updated and are more responsive to some of these issues than they were before.

Model Update Process

Travel models need to be updated periodically. At a minimum, they must be recalibrated with new data as it becomes available. In addition, their structures must be updated to maintain currency with evolving research and the state-of-the-practice. The Boston Metropolitan Planning Organization regional model set, which is maintained by the Central Transportation Planning Staff (CTPS), is in the process of being updated for these reasons and in order to make it more responsive to the recent federal mandates referred to above. It will be another year before the update process is complete, but that process yielded an "interim" model for use in the Transportation Plan and the PMT.

Steps in Model Update Process

The process of developing a new interim model set involved several steps, the first of which was to acquire a new data base. Early on, some new computer software, notably a land use allocation model, was also acquired. After these acquisitions, many months were devoted to modifying some elements of the model process and completely revamping others. All elements of the process were then connected to one another and implemented on a mainframe computer.

Model calibration was then undertaken. Calibration refers to repeatedly running the model set and adjusting certain of its components until it replicates current regional travel patterns at an acceptable level of accuracy. Once the model set was calibrated to current conditions, it was used to forecast future conditions associated with the various scenarios described in this PMT.

New Data Used in Model Update

Acquiring new data was crucial to the model update process. Several types of data, including the following, were obtained:

- Characteristics of region's travelers and of their trips
- Current and forecast regional population and employment
- Community land use and zoning information
- Traffic and transit counts

Among the more important data sources was a travel diary, used to collect information from 3,900 of the region's households. Descriptive data about households and their members was obtained, as was detailed information about the trips they make each day. This information was expanded to represent all of the region's residents and used to refine and reformulate certain portions of the model set. Socio-economic data from the 1990 U.S. Census supplemented the survey data.

CTPS developed a comprehensive file of current population and employment from various sources, including the Metropolitan Area Planning Council (MAPC), the 1990 U.S. Census, the Massachusetts Department of Employment and Training and a commercial vendor. Forecasts of future-year population and employment were obtained from the MAPC. Community land use and zoning information was collected from the MAPC and individual towns and used in the land use allocation model.

Current traffic and transit ridership counts were acquired from the state transportation agencies and other sources and used in model calibration.

New Interim Model Versus Old Models

The new interim model differs from those previously used at CTPS in several key respects. First, it is a single comprehensive regional model, used for highway, transit and high-occupancy vehicle (HOV) forecasting. In the past, three separate sets of models were used for each of these travel modes. The new model set is based entirely on new data, as described above, and incorporates many modified and brand-new steps. Because of these features, the new model is more accurate and sensitive to a wider array of policy variables than were the old ones. In short, it can do more things and do them better than the old models.

The integration of a land use allocation model with the transportation models radically changed the nature of the regional model process. In the past, population and employment forecasts input to the transportation models were always pre-determined and they remained unchanged in the modeling process. Now the land use allocation model allows us not only to forecast the impact of population and employment on transportation, but also to test how transportation might, in turn, shift the patterns of those variables across the region.

Regional employment forecasts used in the new model set are different from those used in the old models. The differences in employment projections between the old and new models translate into differences in the future trips that are generated, in part, from those projections. The old forecasts implied a central Boston employment growth of about 30 percent between 1987 and 2010. The new MAPC forecasts imply a central Boston employment growth of only seven-to-eight percent between 1990 and 2020. In consequence, the forecast of central Boston-bound trips is now lower than before. In particular, since most transit trips are made to and from that area, systemwide transit ridership forecasts output from the new model are lower than before.

Step by Step Description of Model Steps

The transportation model used in the PMT is similar to those used in most large North American cities. It is commonly referred to as the four-step urban travel demand forecasting process or simply as the four-step process. There are actually several more steps to the process; the four steps refer to the major ones. The four steps are: trip generation, trip distribution, mode split and trip assignment. With the addition of a land use allocation model, there are five major steps in the model process.

In the course of constructing a model set, the region was subdivided into small geographic areas called traffic analysis zones or simply zones. These zones, many of which are similar in size to census tracts, serve as the basic geographic units for which trips are forecast. Also in the model development stage, the region's transportation supply, in the form of roadways and transit lines, was represented in computerized networks. These networks are used to derive travel times by travel mode from each zone to every other one. These times are then used in the trip distribution and mode split steps. The networks themselves are used in the trip assignment step. The zone system and the networks are connected to one another to allow for interaction between demand and supply.

Land Use Allocation Model

The land use allocation model spatially allocates forecasts of total regional population and employment among traffic analysis zones. Employment for a given forecast year is allocated to a given zone on the basis of historical levels of employment and population in that zone, total land area in the zone and the accessibility of that zone from other zones where people live. Population is allocated to a given zone based on its historical population, forecast employment level, amount of residential land, vacant developable land and the accessibility of that zone to other zones where people work.

Use of an integrated land use/transportation model allows for a linkage between the locations of activities and transportation system accessibility. Land use models used alone ignore the effects of spatial activity allocation on the transportation system. Transportation models used alone ignore the effects of transportation systems on the spatial allocation of activities.

Trip Generation

The trip generation model takes the allocated population and employment from the land use allocation model and translates that to trips into and out of each zone. It does so for several different trip purposes (work, school, shopping, social, personal business). This is an extremely important step because it yields the basic number of trips in the regional transportation system. Subsequent steps simply allocate those trips spatially, modally and temporally. Completely new trip generation equations were developed in the model update process.

Trip Distribution

Trip distribution spatially allocates the trips generated in the previous step. Trip generation deals solely with how many trips begin or end in a given zone, without reference to where the other ends of those trips are located. Distribution links trips among zones: it deals with where all trips begin and end. Trips that start in a given zone are forecast to end in another given zone as a function of how far apart the two zones are from each other and how many trips each zone generates in total. The longer the travel time between two zones, the fewer trips will flow between them, all other things being equal. On the other hand, the more total trips a zone generates, relative to all zones, the greater the "pull" it will have on a given origin zone; hence, the more of that origin zone's trips it will attract to itself. Distribution results in a matrix of trips among zone's for each trip purpose. This model was modified somewhat in the update process, but its basic structure remained unchanged from previous model versions.

Mode Split

In the mode split (or mode choice) step, the matrices of trips by purpose output from distribution are allocated to competing travel modes. The model that does this considers the times and costs associated with the competing modes and certain characteristics (e.g., auto ownership, forecast with one of the sub-models in the model process) of the travelers being modeled. Work trips are split among the transit, drive alone, 2-person carpool and 3-or-more person carpool modes. Non-work trips are just split between transit and automobile, irrespective of automobile occupancy. This model is critically important for the PMT because it predicts shifts from the auto to the transit mode that could be expected to occur as a result of implementing various transit projects. The model update process resulted in a brand-new work trip mode choice model.

Trip Assignment

The final step in the model process is trip assignment. In this step, the trips split by mode from the previous step are assigned to the appropriate computerized networks in order to predict which routes those trips will choose in the highway and transit networks. It is from this step that we produce statistics such as regional vehicle-miles-traveled, vehicle-hours-traveled and average operating speed. From this procedure, we also produce predicted traffic volumes along specific roadways and transit ridership on specific lines. Trip assignment procedures were modified in the model update process.

Also output from trip assignment are highway travel times under congested conditions and transit travel times. These are combined and input back into the land use model in order to forecast how transportation system accessibility, measured by travel times, might lead to a reallocation of population and employment. These times are also input back into the trip distribution and mode choice steps as well, and for any given model scenario, those steps and trip assignment are run through a second or even third time in order to reach a rough equilibrium state among all steps of the land use/transportation model set.

After the travel models are run, regional air pollution emissions can be calculated. This is done by combining information from Environmental Protection Agency (EPA)-approved emissions models with the results from the trip assignment procedures.

Future Model Development

As stated previously, development of the travel demand model for the Boston region is not complete. The model used for the Transportation Plan is termed "interim"; a final model will be available in 1994. It will differ from the interim model in three broad respects. First, CTPS will have completely redone certain steps in the model that, for now, have simply been modified or left alone. The trip distribution model will, for instance, probably be completely reformulated to make it responsive to travel cost as well as to time.

Second, CTPS will have collected and used additional data to refine the model further. This will, for example, include some survey work to obtain information on unique trip generators such as sports complexes and military installations. Trips to and from these kinds of facilities are not well represented in the standard model process described above. Getting better information about them will enhance the accuracy of the forecasts.

Finally, by next year, CTPS will have tied the individual model steps together more tightly and calibrated the entire land use/transportation model set more precisely. At present, the land use allocation model, being brand-new in the process, does not yield results as satisfactory as will be required in the future. The trip assignments must be further refined in order to enhance their accuracy at the level of individual roadways and transit lines.

Update of 2010 Forecasts to 2020

As mentioned earlier, the 2020 Person Triptable (resulting from Trip Distribution step) used in the Interim Regional Model was developed using more recent population and employment forecasts produced by the MAPC. These forecasts indicate that the growth in downtown employment would be only eight percent from 1992 to 2020 and that regional employment would grow by about 15 percent during the same period. The population for the entire region was assumed to grow at an average rate of 1.7 percent. However, some cities were expected to grow more rapidly than the others. The percentage growth assumed for each city in the Interim Model differs significantly from what was assumed in the 2010 model.

Though the recently forecasted employment growth for downtown Boston between 1992 and 2020 is much less than had been previously projected, the total number of trips entering the CBD in 2020 is projected to be only slightly less than with the previous 2010 projections. This is largely a result of a more sophisticated method being used for the 2020 triptable than had previously been used for the 2010 triptable. The 2010 triptable was developed by factoring 1987 triptable based on projected employment and population growth, with the total number of trips and their distribution dependent on the 1987 triptable. As a result, in the development of 2010 triptable, the proportion of downtown bound trips for different trip purposes was assumed to stay the same between 1987 and 2010. The 2020 triptable was developed independent of prior trip tables, used better trip generation models, and was based on more recent population and employment projections. The implied trip generation rates and the proportion of non-work trips destined to downtown Boston in the new model set are slightly higher than the old models.

Method Used to Update PMT Ridership Forecasts

The differences between the 2020 ridership projections and 2010 projections are largely due to the differences between the 2020 and 2010 triptables. Within the amount of time available for the PMT update, it was not possible to rerun all of the PMT alternatives using the 2020 triptable. Instead, a simpler yet technically sound method involving rerunning a sample of projects was used to develop a set of factors that was then applied to other alternatives. This method consisted of the following steps.

- Determine changes in travel to the core area from each corridor.
- Group similar transit projects.
- Select representative projects by category and geographical area.
- Rerun the entire model for the representative projects using the new 2020 triptable.
- Compare the 2020 ridership results with the previous 2010 estimates and calculate the percentage difference.
- Apply the appropriate factor to the 2010 ridership estimates of all the other projects within the same category and geographical area to obtain the year 2020 estimates.

To determine changes in travel by corridor and transit mode, the base case alternative was rerun using the new 2020 triptable. Transit trips were aggregated by corridor and transit sub-mode. These results were compared to the base case estimates for the year 2010. This comparison highlighted several differences in the way trips will be geographically distributed from the outer suburbs to downtown Boston between the two horizon years, 2010 and 2020 (see Table E-1).

Table E-1
Projected Trips to Boston Central Business District

From	2010 Projections	2020 Projections	Difference Factor
North Shore	42,780	67,030	1.56
North	72,840	78,450	1.08
Northwest	74,880	77,580	1.04
West	107,050	100,350	0.94
Southwest	49,960	39,850	0.80
South Shore	137,770	85,590	0.62
CBD	46,090	72,770	1.57
Total	**531,370**	**521,620**	

In general, regardless of mode, the 2020 projections indicate that there will be more trips from northern suburbs to Boston proper than had previously been projected for 2010. However, from the southern suburbs, there will be fewer trips to Boston proper in 2020 than had been previously estimated for 2010. Although the southern suburbs are expected to experience a higher employment and population growth than the rest of the region, a high proportion of the new trips generated in this area will be attracted by the employment and retail centers within the same areas. As a result, a lower proportion of the new trips from the south will be made to the core area.

The distribution of transit trips also differed by mode. To take this into account, the PMT alternatives were broadly grouped under nine categories, and several representative projects from each category were rerun using 2020 inputs. The nine categories were:

- Commuter rail extensions
- Rapid transit extensions
- Improved run times on commuter rail lines
- New commuter rail stations
- New express bus services
- Circumferential transit service
- Ferry services
- Logan airport related improvements
- Parking expansions

Based on the 2020 results for the sample projects that were rerun, update factors were developed for different combinations of transit mode and geographical area. These factors, which are shown below, were then applied to the 2010 estimates for projects that were not rerun.

Transit Service	Update Factor
Green Line extensions	1.13
Red Line north-related projects	1.20
Red Line south-related projects	0.70
Blue Line-related projects	1.50
New MBTA bus options	1.15
Route 128 circumferential bus	0.90
MBTA express bus improvements	0.95
All Parking expansion-related	0.90
All Ferry-related projects	0.95
Blue-Red connector	1.13
All Logan-related improvements	1.13
Inner Circumferential Transit	1.25
Orange line extension, south	0.86

Appendix F
Project Characteristics, Performance Measures and Evaluation Criteria

During the 18 months of the PMT Update process, over 70 potential expansions or changes to MBTA and MBTA-related services were examined in detail. This examination consisted of the determination of projected ridership for each project in 2020,[1] operating and capital costs, fare revenue, and service, traffic and air quality impacts. Each project was then evaluated based on a number of measures addressing utilization, cost-effectiveness, and a number of financial, air quality, and other impacts. This appendix describes the evaluation process, and describes and presents all of the project characteristics, performance measures, and qualitative rankings developed for each project examined in the PMT. (Appendix G describes the interpretation of these data, and conclusions, on a project-by-project basis.)

Evaluation Process

The evaluation of projects generally consisted of five steps: (1) project definition, (2) determination of project characteristics, (3) calculation of performance measures and the development of qualitative rankings, (4) interpretation of data, and (5) conclusions. For most projects, new data was developed or existing data was updated.[2] Each step consisted of the following:

1. **Project Definition** The first step was to define the assumed physical and operating attributes of each project. This included the mode, alignment, station locations, level of service, span of service, and changes in connecting and parallel services. For

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[1] Note that through most of the PMT process, ridership estimates were produced for 2010. To provide for consistency with Regional and State Transportation plans, these estimates have been updated to reflect MAPC and CTPS projections of population, employment, and travel for 2020. (See also Appendix E.)

[2] Exceptions were Washington Street Replacement Service, Old Colony Commuter Rail Restoration, and South Boston Piers Transitway, and the North Station - South Station Rail Link. For the first three projects, which were "base case" projects, information for the EIR/ENFs is presented but no additional analysis was conducted. For the Rail Link, information developed by the Central Artery Rail Link Task Force was used in the PMT analysis.

each project, the mode and alignment were chosen in specific terms. However, station locations were more general, such as at a street intersection, rather than on a certain parcel. Operating characteristics (level of service and span of service) were generally defined to be the same as for other comparable services. Impacts on other services, if any, were defined based on the judgments of MBTA and project staff. A description of how each project was defined is included in Appendix G.

2. **Determination of Project Characteristics** A large number of "project characteristics" were developed for each project. These characteristics, which are described in detail in the next section, included projected ridership for each project in 2020, operating and capital costs, fare revenue, and service, traffic and air quality impacts. Some important notes about these figures are as follows:

   — Ridership was projected using CTPS' Regional Transit Model as described in Appendix E.
   — Operating costs were developed based on actual 1991 MBTA operating costs, allocated by mode on a cost per vehicle service hour basis. This information was provided by the MBTA Budget office.
   — Capital costs were developed using either unit costs derived from recently implemented projects or from recent feasibility studies or EIRs. All capital costs are presented in 1993 dollars.
   — Fare revenue is estimated based on the projected ridership and 1993 average fares for each mode and zone.
   — Air quality impacts are based on estimates of VMT changes that were produced during the ridership estimation process. (See Appendix H for additional information on air quality issues.)

3. **Calculation of Performance Measures/Development of Qualitative Rankings** Based on the ridership, cost, air quality, and other characteristics that were developed for each project, a number of quantitative performance measures were calculated. For issues for which quantitative measures could not be developed, a number of qualitative measures and rankings were developed. Both the quantitative and qualitative measures are described in detail in the Evaluation Criteria section of this appendix.

4. **Interpretation of Data** Once project characteristics, performance measures, and qualitative rankings had been developed, these data needed to be interpreted. With the diversity of project types represented in the list of proposed changes and expansions, not all of the evaluation criteria could be applied equally to all projects. However, in most cases, the criteria that were considered to be the most important were number of new transit trips, capital cost per new transit trip, net operating cost, travel time savings, percent emissions reduction, and cost per kilogram of Volatile Organic Compound (VOC) eliminated. The other factors were considered, especially in cases where the above mentioned factors did not capture all of the salient characteristics of a project (for example, in the restoration/replacement of trolley service to Arborway), but not to as great an extent as the aforementioned measures. The interpretation of the data and a discussion of the most important impacts of each project is included in Appendix G.

5. **Conclusions** Based on the interpretation of the available information described in step (4), conclusions were made as to each project's merit. These conclusions were used to develop the recommend program described in the PMT report.

It is important to note that projects were analyzed at level of detail appropriate for systems level planning. The objective was to identify those projects that would appear to be the most effective and worthy of further, more in-depth study. Many of the projects recommended in the PMT require environmental impact and alternatives analysis before they can proceed to design and construction.

It is also important to note that ridership projections, which are for the year 2020, depend to a great extent, on growth in population and employment. If these projects were built tomorrow, they would not achieve the ridership levels forecast by the regional model because the projected growth has not yet occurred. Operating costs, on the other hand, are presented in 1991 dollars, fare revenue figures are based on current (1993) fare levels, and capital costs are in 1993 dollars. Implicit within the use of these figures is the assumption that costs and fare revenue will increase at the same rate as inflation. Costs could rise faster or slower than inflation depending on the wage rate, labor agreements, changes in technical efficiencies in both construction and operations, and future fare increases.

Project Characteristics

A large number of quantitative project characteristics were developed for each project. As shown in Table F-1 and described below, these focused on ridership, service levels, operating and capital costs, fare revenue, air quality, traffic impacts, and service quality. Table F-1 contains all of the statistics associated with each project examined in the PMT. The columns are as defined below.

Ridership

- Total New Trips Total new trips attracted to the new/upgraded service or facility for the year 2020. This includes both riders diverted from the auto mode and riders diverted from other transit modes. Total new trips is equal to the total number of new passenger boardings on the service, regardless of the direction of travel.

- New Transit Trips The number of total new weekday transit trips on the new/upgraded service or facility for the year 2020. This figure includes only riders diverted from auto trips. It does not include any riders that may be diverted from other transit modes.

- Auto Reduction The reduction in the number of automobile trips that occurs as a result of the new/upgraded service or facility. This is the difference between the amount of traffic projected for 2020 with and without the service, and is based on an auto occupancy rate of 1.29 passengers per vehicle.

Amount of Service

- Vehicle Service Miles This is the net change in service miles traveled by vehicles offering the new service. A vehicle is defined as a single rail car or bus—a six-car Red Line train traveling for one hour would accumulate six vehicle service hours.

- Vehicle Service Hours This is the net change in service hours performed by vehicles offering the new service.

Costs/Revenues

- Total Capital Cost The cost to construct the new facility or service, including vehicle costs. The cost estimates are in 1993 dollars. The sources for the capital costs are based on estimates from MBTA consultant studies, estimates from the MBTA, or generated by CTPS using standard transit construction cost figures.

- Annualized Capital Cost The cost to maintain the facility on an ongoing basis. These costs, also in 1993 dollars, were calculated using the life-cycle costing method (see Chapter 6 for a full discussion).

- Annual Operating Cost The cost to operate the service. These figures were calculated by multiplying the number of vehicle service hours by the average hourly operating cost for that mode of transit vehicle. The average costs were provided by the MBTA.

- Annual Fare Revenue The amount of fare revenue expected to be generated by the new service. These figures were derived either through the regional model, or by applying average fares to the new ridership generated.

Air Quality

- VOC Reduction The number of kilograms of volatile organic compounds estimated to be eliminated by the project. These figures were derived by multiplying the reduction in vehicle miles traveled by an emissions factor from Mobile5A. (For further details, see Appendix H.)

Traffic

- VMT Reduction The number of vehicle miles traveled eliminated by drawing people out of automobiles and onto the new service. This figure is calculated by the regional model.

- VHT Reduction The number of vehicle hours of travel eliminated by drawing people out of automobiles and onto the new service. This figure is calculated by the regional model.

Service Quality

- Travel Time Savings The travel time savings that would be accrued by those transit users in the year 2020 who would be on the system before the improvements are made.

Table F-1

Project Characteristics

Based on 2020 Projections

Project	Note	Ridership			Amount of Service		Costs/Revenues				Air Quality	Traffic		Service Quality	
		Total New Trips (/Weekday)	New Transit Trips (/Weekday)	Auto Reduction (/Weekday)	Veh Ser Miles (/Weekday)	Veh Ser Hours (/Weekday)	Total Capital Cost ($000s)	Ann Capital Cost ($000s)	Ann Oper Cost ($000s)	Ann Fare Revenue ($000s)	VOC Reduction (kg/WD)	VMT Reduction (/WD)	VHT Reduction (/WD)	Travel Time Savings (Hrs/WD)	Travel Time Savings (Hrs/Yr)
							Note 1			Note 2					
1. Upgrade the System															
A. Faster Commuter Rail Service (Express/Local 2010)															
• Rockport/Ipswich Line		2,150	1,463	1,134	3,772	30	$18,600	$735	$1,217	$870	30.6	25,063	1,288	803	200,750
• Haverhill/Reading Line		4,537	2,886	2,237	2,213	57	$39,104	$1,531	$2,327	$1,437	80.7	66,118	2,132	514	128,500
• Lowell Line		4,602	2,561	1,985	702	4	$17,052	$682	$156	$1,409	70.1	57,499	1,846	1,015	253,750
• Fitchburg Line		1,138	956	741	3,271	103	$72,906	$2,905	$4,196	$564	26.1	21,421	992	298	74,500
• Framingham Line		1,464	576	447	223	48	$18,300	$955	$1,942	$314	16.3	13,320	636	66	16,500
• Needham Line		555	158	122	333	37	$23,268	$931	$1,519	$50	1.5	1,245	83	63	15,750
• Franklin Line		2,580	1,245	965	1,643	72	$45,816	$2,033	$2,904	$711	26.6	21,788	439	143	35,750
• Attleboro/Stoughton Line		525	490	380	1,350	21	$20,790	$832	$847	$275	11.6	9,548	424	174	43,500
B. Bus Service Improvements In/to Downtown Boston															
• Better Downtown Bus Circulation		11,875	7,220	5,597	707	76	$6,100	$504	$1,265	$1,341	76.6	62,614	3,895	1,733	433,250
• Sumner Tunnel Approach		110	0	0	0	-5	$100	$4	($86)	$0	0.0	0	0	L	L
2. Intermodal Connections															
A. Park and Ride Expansion**															
• Intercept Stations along Major Highways		14,310	3,980	3,085	NA	NA	$60,200	$2,408	L	$2,219	69.4	56,880	1,854	465	142,290
• Other Rapid Transit Expansion		14,490	3,690	2,860	NA	NA	$128,940	$5,158	L	$535	30.6	25,092	923	246	75,276
• Other Commuter Rail Expansion		19,080	8,352	6,474	NA	NA	$89,570	$3,583	L	$2,777	120.2	98,550	2,790	315	84,735
• Other Bus		2,410	1,640	1,271	NA	NA	$2,600	$104	L	$469	26.3	21,596	404	70	20,020
B. New Commuter Rail Stations/Additional Service															
• Alewife	3	1,020	348	270	NA	NA	$7,560	$322		$80	4.7	3,840	196	319	85,811
• Wonderland	3	7,200	1,080	837	339	11	$9,316	$1,066	$461	$247	9.5	7,770	278	1,275	342,975
• Riverside	3	876	876	679	107	12	$4,308	$134	$444	$507	6.1	4,983	249	576	154,944
• Mattapan	3	1,680	189	147	176	5	$8,150	$333	$125	$43	1.4	1,117	63	49	13,181
• JFK/UMASS	3	952	266	206	NA	NA	$1,560	$62		$61	5.4	4,466	252	266	71,554
• Ruggles		984	328	254	NA	NA	$1,560	$62		$75	3.4	2,776	212	144	38,736
3. Urban Core Distribution															
A. New Ferry Service**															
• North Station to Fan Pier and World Trade Center	4	1,378	L	L	NA		$2,089	$104	$1,555	$0	L	L	L	L	L
• North Station to Navy Yard Pier 4 and Logan Airport	4	713	L	L	NA		$1,702	$85	$1,348	$0	L	L	L	L	L
• South Station to Long Wharf and Navy Yard Pier 4	4	1,045	L	L	NA		$1,410	$71	$1,138	$0	L	L	L	L	L
• Navy Yard Pier 4 to Long Wharf and World Trade Ctr	4	380	L	L	NA		$1,713	$86	$2,045	$0	L	L	L	L	L
• South Station to Navy Yard Pier 11	4	831	L	L	NA		$1,358	$68	$638	$0	L	L	L	L	L
B. Circumferential Transit**	4														
• Core LRT: Sullivan – Ruggles		86,700	18,213	14,119	1,593	130	$1,078,885	$29,767	$4,865	$3,232	141.4	115,913	8,350	9,400	2,876,400
• Full LRT: Airport – JFK/UMass		149,525	34,375	26,647	3,590	365	$1,430,854	$35,776	$13,703	$6,101	184.1	150,925	11,719	6,244	1,910,664
• Bus Improvements		*To be determined in MBTA Crosstown Transit Feasibility St*					$2,350	$196	$1,500	$0					

Table F-1

Project Characteristics

Based on 2020 Projections

		Ridership			Amount of Service		Costs/Revenues				Air Quality	Traffic		Service Quality	
Project	Note	Total New Trips (/Weekday)	New Transit Trips (/Weekday)	Auto Reduction (/Weekday)	Veh Ser Miles (/Weekday)	Veh Ser Hours (/Weekday)	Total Capital Cost ($000s)	Ann Capital Cost ($000s)	Ann Oper Cost ($000s)	Ann Fare Revenue ($000s)	VOC Reduction (kg/WD)	VMT Reduction (/WD)	VHT Reduction (/WD)	Travel Time Savings (Hrs/WD)	Travel Time Savings (Hrs/Yr)
							Note 1			Note 2					
3. Urban Core Distribution (Cont.)															
C. South Boston Piers: South Station to Boylston															
• w/High growth	5	36,000	7,800	2,100			$180,000	($1,050)	($1,594)	($40)	39.9	32,700		2,248	642,857
• w/ Lower growth	5	26,850	6,500	1,700			$180,000	$771	($456)	$280	31.8	26,100		1,733	495,567
D. N. Station--S. Station Rail Link**	4														
Phase 1							$1,853,000								
Phase 2							$1,780,000								
Total	4	57,000	23,000	17,829	37,492		$3,633,000		$47,000	$36,000	446.5	366,000			
E. Red Line - Blue Line Connector**	4	19,210	4,972	3,854	1,480	15	$137,500	$4,580	$456	$1,480	42.4	34,770	961	2,458	752,148
F. Connections to Logan Airport															
• Bus Service from North Station		718	90	70	156	23	$1,097	$91	$438	$12	1.8	1,437	33	59	16,874
• Bus Service from South Station		1,413	45	35	192	29	$1,367	$114	$549	$6	1.0	805	14	153	43,758
• Blue Line Spur to Logan Central Terminal		7,232	2,000	1,550	625	35	$29,400	$1,080	$1,040	$355	16.6	13,601	466	2,269	694,314
• Express Bus from Newton Corner		271	124	96	412	20	$827	$69	$383	$35	1.3	1,032	51	64	18,304
• Express Bus from Waltham (Rt 128 @ Winter St)		192	124	96	634	31	$1,097	$91	$581	$53	1.7	1,356	54	68	19,448
4. New Radial Services															
A. Blue Line Extensions															
• Wonderland to Lynn		11,340	4,860	3,767	7,540	255	$275,000	$11,800	$10,251	$1,431	60.3	49,440	3,600	893	273,258
• Bowdoin to Medford Hillside (Includes Blue-Red Conn.)		32,872	7,283	5,646	9,210	350	$548,430	$15,882	$10,894	$2,144	66.2	54,263	3,322	2,565	784,890
• Bowdoin to Riverside via Esplanade (Rivervision)		70,500	8,000	6,202	13,700	462	$985,500	$32,700	$11,016	$1,688	69.6	57,060	3,800	3,292	1,007,250
• Bowdoin to Riverside via Huntington Ave		81,400	8,700	6,744	14,420	455	$883,500	$33,636	$10,404	$1,864	71.6	58,660	3,900	4,847	1,483,080
• Gov't Center to Riverside via Newbury St		84,610	10,240	7,938	13,700	500	$986,000	$33,600	$12,118	$2,207	101.4	83,150	3,400	6,244	1,910,613
B. Orange Line Extensions															
• Forest Hills to Route 128		13,648	4,704	3,647	-1,715	180	$249,036	$9,454	$1,872	$957	40.2	32,921	2,522	1,525	466,650
C. Green Line Extensions															
• Lechmere to Medford Hillside**		11,560	3,661	2,838	1,170	25	$88,000	$2,875	$2,111	$1,072	47.3	38,770	1,288	1,161	355,266
• Comm Ave to Oak Square	4	32,940	1,006	780	-890	125	$93,800	$3,769	$8,609	$425	8.8	7,232	260	568	173,808
• Restoration of E Line to Arborway**	4	36,160	136	119	-1,128	-179	$56,600	$2,202	($1,484)	$23	0.9	763	54	2,260	691,560
D. Red Line Extensions															
• Ashmont to Mattapan		4,716	1,260	977	1,760	45	$54,800	$1,741	$1,331	$244	10.7	8,736	665	338	103,428
• Alewife to Lexington		8,880	2,376	1,842	7,800	230	$590,038	$12,118	$9,486	$700	43.3	35,508	1,992	737	225,522
E. Bus/Trackless Trolley Services															
• Arborway Trackless Trolley		38,697	316	245	-425	-130	$27,000	$596	($2,554)	$43	2.5	2,068	40	1,262	360,932
• Express Rt 1/128 to Boston via Route 1		2,473	1,944	1,507	761	50	$3,557	$201	$833	$724	33.1	27,094	1,472	698	199,628
• Express Rt 3/128 to Boston via 128 and I-93		3,140	2,355	1,826	916	56	$4,382	$244	$933	$877	31.9	26,163	1,541	315	90,090
• Express Rt 3/128 to Alewife via Rts 128 and 2		2,473	2,047	1,587	682	31	$3,107	$164	$516	$507	27.7	22,667	1,225	515	147,280
• Improved Express Service in the Mass Pike Corridor		523	322	250	69	5	$0	$0	$83	$120	4.2	3,479	81	29	8,294

Table F-1
Project Characteristics

Based on 2020 Projections

		Ridership			Amount of Service		Costs/Revenues				Air Quality	Traffic		Service Quality	
Project	Note	Total New Trips (/Weekday)	New Transit Trips (/Weekday)	Auto Reduction (/Weekday)	Veh Ser Miles (/Weekday)	Veh Ser Hours (/Weekday)	Total Capital Cost ($000s)	Ann Capital Cost ($000s)	Ann Oper Cost ($000s)	Ann Fare Revenue ($000s)	VOC Reduction (kg/WD)	VMT Reduction (/WD)	VHT Reduction (/WD)	Travel Time Savings (Hrs/WD)	Travel Time Savings (Hrs/Yr)
							Note 1			Note 2					
4. New Radial Services (Cont.)															
F. Commuter Rail Extensions															
• Ipswich Line: Ipswich to Newburyport**	4														
Existing Line Improvements		2,150	1,463	1,134	3,772	30	$18,600	$735	$1,217	$670	30.6	25,063	1,288		
Newburyport Extension Segment		1,638	1,438	1,115	1,184	38	$42,800	$1,712	$1,663	$1,253	27.2	22,325	1,225		
Total		3,788	2,901	2,249	4,956	68	$61,400	$2,447	$2,880	$2,124	57.8	47,388	2,513	258	69,402
• Haverhill Line: Wakefield to Topsfield															
Existing Line Improvements		4,056	1,924	1,491	-395	2	$5,000	$167	$3,500	$957					
Topsfield Extension Segment		767	546	423	4,531	156	$87,442	$3,769	$3,117	$308					
Total		4,823	2,470	1,915	4,136	158	$92,442	$3,936	$6,617	$1,265	63.7	52,182	2,340	306	82,314
• Haverhill Line: Haverhill to Plaistow NH	4,6														
Existing Line Improvements		4,537	2,886	2,237	2,213	57	$39,104	$1,531	$2,327	$1,436					
Plaistow Extension Segment		689	286	222	144	27	$26,216	$1,046	$1,173	$283					
Total		5,226	3,172	2,459	2,357	84	$65,320	$2,577	$3,500	$1,718	NA	NA	NA	NA	NA
• Lowell Line: Lowell to Nashua, NH															
Existing Line Improvements		5,759	3,198	2,479	2,544	41	$17,052	$682	$1,785	$1,759					
Nashua Extension Segment		1,482	520	403	1,557	67	$51,652	$1,777	$2,907	$562					
Total		7,241	3,718	2,882	4,100	108	$68,704	$2,459	$4,692	$2,321	100.3	82,251	4,713	3,134	843,046
• Framingham Line: Framingham to Worcester**	4														
Existing Line Improvements		684	264	205			$0	$0		$144					
Worcester Extension Segment		6,012	3,204	2,484	5,382	166	$118,964	$4,261	$7,245	$4,563					
Total		6,696	3,468	2,688	5,382	166	$118,964	$4,261	$7,245	$4,707	81.9	67,140	2,580	1,214	326,566
• Framingham Line: Framingham to Marlborough	4									$1					
Existing Line Improvements															
Marlboro Extension Segment		1,632	774	600	6,140	196	$73,600	$4,028	$8,572	$813	31.5	25,848	1,428	287	64,336
Total															
• Franklin Line: Forge Park/495 to Milford															
Existing Line Improvements		1,928	930	721	138	-7	$45,816	$2,033	($284)	$644					
Milford Extension Segment		383	83	64	517	53	$27,973	$1,891	$2,313	$169					
Total		2,311	1,013	785	655	46	$73,789	$3,924	$2,029	$813	23.0	18,833	308	131	35,239
• Franklin Line: Walpole to Foxborough															
Existing Line Improvements		1,538	810	628	2,676	47	$13,545	$542	$1,894	$415					
Foxborough Segment		38	8	6	671	21	$14,104	$552	$908	$8					
Total		1,576	818	634	3,347	68	$27,649	$1,094	$2,802	$423	20.2	16,568	285	117	31,473
G. Other New Commuter Rail Services															
• New Bedford/Fall River Lines	4	6,465	2,820	2,186	10,670	255	$288,000	$7,665	$12,205	$2,647	83.3	68,279	NA	NA	NA
• New Millis Line		1,823	855	663	3,292	128	$66,728	$2,778	$5,565	$1,201	28.0	22,920	1,200	203	54,607
• Additional CR Service to Dedham Corporate Center		630	0	0							0.0	0	0	0	0

Table F-1
Project Characteristics

Based on 2020 Projections

Project	Note	Ridership Total New Trips (/Weekday)	Ridership New Transit Trips (/Weekday)	Ridership Auto Reduction (/Weekday)	Amount of Service Veh Ser Miles (/Weekday)	Amount of Service Veh Ser Hours (/Weekday)	Costs/Revenues Total Capital Cost ($000s)	Costs/Revenues Ann Capital Cost ($000s)	Costs/Revenues Ann Oper Cost ($000s)	Costs/Revenues Ann Fare Revenue ($000s)	Air Quality VOC Reduction (kg/WD)	Traffic VMT Reduction (/WD)	Traffic VHT Reduction (/WD)	Service Quality Travel Time Savings (Hrs/WD)	Service Quality Travel Time Savings (Hrs/Yr)
							Note 1			Note 2					
5. Suburban Circumferential Movement															
A. Route 128 Circumferential Bus Service		3,474	3,474	2,693	5,340	290	$7,906	$664	$4,823	$861	44.2	36,270	846	NA	NA
B. Feeder Bus to Rapid Transit at Riverside		690	490	380		48	$1,350	$113	$799	$139	9.6	7,840	120	13	3,250
C. Feeder Bus to Commuter Rail in Needham	7	340	0	0		18	$60	$20	$113	$0	0.0	0	0	0	0

Notes:

1. *Capital costs are in 1993 dollars.*
2. *Revenue figures are based on current (1993) fare levels.*
3. *Ridership is daily transfer volume*
4. *Parallel Study*
5. *Results from DEIS/SDEIR, November 1992. High growth scenario is comparable to 2010 PMT forecasts*
6. *Results from "Draft Report: Ridership Potential: Plaistow, NH – Boston, MA Commuter Rail Service," Frederic R. Harris, Inc., November 1992*
7. *This service is assumed to be privately operated. The capital cost of vehicles would be included in the contract cost for operations.*

Codes:

NA = Not Available or Not Applicable

L = Low or insignificant

*** Central Artery Mitigation/SIP Project*

Evaluation Criteria

Using the project characteristics described in the previous section, a number of quantitative performance measures were developed. In addition, in order to consider non-quantitative impacts, a number of qualitative measures were also developed. As described below, these quantitative and qualitative measures became the basis for the evaluation of projects.

The use of the criteria was aimed at achieving the following objectives:

- Pursuing the most cost-effective of the proposed projects.
- Evaluating projects fairly and consistently.
- Using quantifiable performance-based standards to the maximum feasible extent.

The proposed performance measures were developed based on a number of considerations, including the policies in the PMT Phase 2 report, consistency with other similar studies, the intent of ISTEA, and the criteria used by MBTA Advisory Board's Capital Planning Committee. The resulting performance measures fall into nine categories: (1) Utilization, (2) Cost-Effectiveness, (3) Financial Impacts, (4) Air Quality Impacts, (5) Service Quality and Coverage, (6) Impact on Existing System, (7) Economic Impacts, (8) Compatibility with Land Use Plans, and (9) Compatibility with Other Plans.

As mentioned above, the criteria that were considered to be the most important were number of new transit trips, capital cost per new transit trip, net operating cost, travel time savings, percent emissions reduction, and cost per kilogram of volatile organic compound eliminated. The other factors were used to evaluate projects, but not to as great an extent.

In detail, the performance measures that were used were as described below. These measures are presented on a project-by-project basis in Table F-2.

Utilization

- Total New Trips Total new trips attracted to the new/upgraded service or facility for the year 2020. This includes both riders diverted from the auto mode and riders diverted from other transit modes. Total new trips is equal to the total number of new passenger boardings on the service, regardless of the direction of travel.

- New Transit Trips The number of total new weekday transit trips on the new/upgraded service or facility for the year 2020. This figure includes only riders diverted from auto trips. It does not include any riders that may be diverted from other transit modes.

- Riders/Vehicle Service Hour (VSH) and Riders/Vehicle Service Mile (VSM) These two figures provide a measure of how well utilized a service would be. A vehicle is defined as a single rail car or bus—a six-car Red Line train traveling for one hour would accumulate six vehicle service hours.

Table F-2
Evaluation Criteria

	Utilization				Cost-Effectiveness					Air Quality Impacts		Service Quality and Coverage								Impact on System			Economic Impacts		Land Use Impacts	
	Total New Trips	New Transit Trips (Weekday)	Riders/Vehicle Service Hour	Riders/Vehicle Service Mile	Farebox Ratio	Investment/New Daily Transit User	Annualized Cost/New Daily Transit User	Annualized Cost/Hr of Travel Time Savings	Annual Operating Subsidy (000s)	% Emissions Reduction	Capital Cost/kg VOC Eliminated (000s)	Improved Connections	System Accessibility	Distribution of Service	Unmet Needs	Travel Time Savings	Safety/Security	Comfort/Convenience	Crowding	Preservation of Existing System	Preservation of Future Options	Efficiency/Effectiveness	Economic Development Potential	Potential for Private-Sector Participation	Supports Urban Core	Supports Suburban Compact Development
1. Upgrade the System																										
A. Faster Commuter Rail Service (Express/Local 2010)																										
• Rockport/Ipswich Line	2,150	1,463	71.7	0.6	72%	$25,427	$1,005	$4	$346	0.04%	$608					■		■	■	▨	▨	■			▨	▨
• Haverhill/Reading Line	4,537	2,886	79.1	2.1	62%	$27,099	$1,061	$12	$890	0.10%	$485					■		■	■	▨	▨	■			▨	▨
• Lowell Line	4,602	2,561	1,198.4	6.6	904%	$13,317	$533	$3	-$1,253	0.08%	$243					■		■	■	▨	▨	■			▨	▨
• Fitchburg Line	1,138	956	11.0	0.3	13%	$152,523	$6,077	$39	$3,632	0.03%	$2,790					▨		▨	▨	▨	▨				▨	▨
• Framingham Line	1,464	576	30.6	6.6	16%	$63,542	$3,316	$56	$1,628	0.02%	$1,126							▨	▨	▨	▨				▨	▨
• Needham Line	555	158	14.8	1.7	3%	$294,532	$11,785	$59	$1,469	0.00%	$15,319							▨	▨	▨	▨				▨	▨
• Franklin Line	2,580	1,245	36.0	1.6	24%	$73,600	$3,266	$57	$2,193	0.03%	$1,724							■	■	▨	▨	▨			▨	▨
• Attleboro/Stoughton Line	525	490	25.1	0.4	32%	$84,857	$3,394	$19	$572	0.01%	$1,785							■	■	▨	▨	▨			▨	▨
B. Bus Service Improvements in/to Downtown Boston																										
• Better Downtown Bus Circulation	11,875	7,220	156.3	16.8	106%	$1,690	$140	$1	-$76	0.09%	$80	■	▨	▨	▨	■	▨	■				■			■	▨
• Sumner Tunnel Approach	110	0	NA	NA	NA	NA	NA	NA	-$86	0.00%	NA															
2. Intermodal Connections																										
A. Park and Ride Expansion**																										
• Intercept Stations along Major Highways	14,310	3,980	NA	NA	NA	$30,251	$1,210	$17	NA	0.08%	$868	■			▨	▨			▨			▨		▨	▨	
• Other Rapid Transit Expansion	14,490	3,690	NA	NA	NA	$69,886	$2,795	$69	NA	0.04%	$4,212	■			▨	▨			▨			▨		▨	▨	
• Other Commuter Rail Expansion	19,080	8,352	NA	NA	NA	$21,449	$858	$42	NA	0.14%	$745	■			▨	▨			▨			▨		▨	▨	
• Other Bus	2,410	1,640	NA	NA	NA	$3,171	$127	$5	NA	0.03%	$99	■			▨				▨			▨		▨	▨	
B. New Commuter Rail Stations/Additional Service																										
• Alewife	1,020	348	NA	NA	NA	$43,448	$1,853	$4	-$80	0.01%	$1,614	▨		▨		▨					▨					
• Wonderland	7,200	1,080	627.5	21.2	54%	$17,252	$1,973	$3	$214	0.01%	$983	■		■		■		▨			▨	▨				
• Riverside	876	876	73.0	8.2	114%	$9,836	$306	$1	-$63	0.01%	$709	▨		▨		▨					▨					
• Mattapan	1,680	189	373.3	8.5	35%	$86,243	$3,524	$25	$82	0.00%	$5,981	■		■							▨	▨	▨		▨	
• JFK/UMass	952	266	NA	NA	NA	$11,729	$469	$1	-$61	0.01%	$286	▨		▨		▨					▨					
• Ruggles	984	328	NA	NA	NA	$9,512	$380	$2	-$75	0.00%	$461	▨		▨		▨					▨		▨		▨	
3. Urban Core Distribution																										
A. New Ferry Service**																										
• North Station to Fan Pier and World Trade Center	1,378	L	NA	NA	NA	NA	NA	NA	$1,555	L	NA	▨		▨										▨	▨	
• North Station to Navy Yard Pier 4 and Logan Airpor	713	L	NA	NA	NA	NA	NA	NA	$1,348	L	NA	▨		▨										▨	▨	
• South Station to Long Wharf and Navy Yard Pier 4	1,045	L	NA	NA	NA	NA	NA	NA	$1,138	L	NA	▨		▨										▨	▨	
• Navy Yard Pier 4 to Long Wharf and World Trade C	380	L	NA	NA	NA	NA	NA	NA	$2,045	L	NA	▨		▨										▨	▨	
• South Station to Navy Yard Pier 11	831	L	NA	NA	NA	NA	NA	NA	$638	L	NA	▨		▨										▨	▨	
B. Circumferential Transit**																										
• Core LRT: Sullivan – Ruggles	86,700	18,213	666.9	54.4	66%	$118,474	$3,269	$10	$1,633	0.17%	$7,629	■		■	■	■	▨	■	■		▨		■		■	
• Full LRT: Airport – JFK/UMass	149,525	34,375	409.7	41.7	45%	$83,250	$2,082	$19	$7,602	0.22%	$7,771	■		■	■	■	▨	■	■				■		■	
• Bus Improvements	*To be determined in MBTA Crosstown Transit Feasibility Study*											■		■	▨	▨	▨	▨	▨		▨		▨		■	

Table F-2
Evaluation Criteria

	Utilization				Cost-Effectiveness					Air Quality Impacts		Service Quality and Coverage							Impact on System			Economic Impacts		Land Use Impacts	
	Total New Trips	New Transit Trips (Weekday)	Riders/Vehicle Service Hour	Riders/Vehicle Service Mile	Farebox Ratio	Investment/New Daily Transit User	Annualized Cost/New Daily Transit User	Annualized Cost/Hr of Travel Time Savings	Annual Operating Subsidy (000s)	% Emissions Reduction	Capital Cost/kg VOC Eliminated (000s)	Improved Connections	System Accessibility	Distribution of Service	Unmet Needs	Travel Time Savings	Safety/Security	Comfort/Convenience	Crowding	Preservation of Existing System	Preservation of Future Options	Efficiency/Effectiveness	Economic Development Potential	Potential for Private-Sector Participation	Supports Urban Core	Supports Suburban Compact Development
3. Urban Core Distribution (Cont.)																										
C. South Boston Piers: South Station to Boylston																										
• w/High growth	36,000	7,800	NA	NA	3%	$46,154	-$269	-$2	-$1,554	0.05%	$4,512	■		■	■	■		■				▨	▨		■	
• w/Lower growth	26,850	6,500	NA	NA	-61%	$55,385	$237	$2	-$736	0.04%	$5,653	■		■	▨	■		■				▨	▨		■	
D. N. Station–S. Station Rail Link**	57,000	23,000	NA	1.5	77%	$315,913	$0	NA	$11,000	0.54%	$8,136	■		■	■	■	▨	■	■	■	■	■			■	■
E. Red Line - Blue Line Connector**	19,210	4,972	1,280.7	13.0	325%	$55,310	$1,842	$6	-$1,024	0.05%	$3,241	■	■	■	■	■	▨	■	■	■	■	■			■	
F. Connections to Logan Airport																										
• Bus Service from North Station	718	90	31.2	4.6	3%	$24,378	$2,024	$5	$426	L	NA	■		■							▨					
• Bus Service from South Station	1,413	45	48.7	7.4	1%	$60,756	$5,049	$3	$543	L	NA	■		■		▨					▨					
• Blue Line Spur to Logan Central Terminal	7,232	2,000	206.6	11.6	34%	$29,400	$1,080	$2	$685	0.02%	$1,772	■		■		■		■				▨			▨	
• Express Bus from Newton Corner	271	124	13.6	0.7	9%	$13,339	$1,106	$4	$348	0.00%	$657	■		■							▨					
• Express Bus from Waltham (Rt 128 @ Winter St)	192	124	6.2	0.3	9%	$17,694	$1,469	$5	$528	0.00%	$663	■		■							▨					
4. New Radial Services																										
A. Blue Line Extensions																										
• Wonderland to Lynn	11,340	4,860	44.5	1.5	14%	$113,169	$4,856	$43	$8,820	0.07%	$4,559	■		■	■	▨		▨	▨			▨	■		■	
• Bowdoin to Medford Hillside	32,872	7,283	93.9	3.6	20%	$150,606	$4,361	$20	$8,750	0.08%	$8,284	▨	▨	■	■	■		▨	▨				■		■	
• Bowdoin to Riverside via Esplanade (Rivervision)	70,500	8,000	152.6	5.1	15%	$246,375	$8,175	$32	$9,328	0.08%	$14,157	■	▨	▨	▨	■		▨	▨			▨			■	
• Bowdoin to Riverside via Huntington Ave	81,400	8,700	178.9	6.6	18%	$203,103	$7,732	$23	$8,540	0.09%	$12,345	■	▨	▨	▨	■		▨	■			▨			■	
• Gov't Center to Riverside via Newbury St	84,610	10,240	169.2	6.2	18%	$192,578	$6,563	$18	$9,911	0.12%	$9,720	■	▨		▨	■		▨	■			▨			■	
B. Orange Line Extensions																										
• Forest Hills to Route 128	13,648	4,704	75.8	-8.0	51%	$105,882	$4,019	$20	$915	0.05%	$6,201	■		■	▨	■			▨				▨		■	
C. Green Line Extensions																										
• Lechmere to Medford Hillside**	11,560	3,661	462.4	9.9	51%	$48,074	$1,571	$8	$1,039	0.06%	$1,860	■		■	■	■		■	▨		▨	▨	■		■	
• Comm Ave to Oak Square	32,940	1,006	263.6	-37.0	5%	$186,481	$7,493	$22	$8,184	0.01%	$10,631			▨		▨					▨				■	
• Restoration of E Line to Arborway**	36,160	136	-202.0	-32.1	-2%	$834,808	$32,478	$3	-$1,507	0.00%	$60,824	▨		■	▨	■		■	▨	▨	▨	■			■	
D. Red Line Extensions																										
• Ashmont to Mattapan	4,718	1,260	104.8	2.7	18%	$86,984	$2,763	$17	$1,087	0.01%	$5,142	■	■	■		■	▨	■	▨	■	■	■	▨		■	
• Alewife to Lexington	8,880	2,376	38.6	1.1	7%	$496,665	$10,200	$54	$8,786	0.05%	$13,621	▨				■										
E. Bus/Trackless Trolley Services																										
• Arborway Trackless Trolley	38,697	316	-297.7	-91.1	-2%	$170,886	$3,770	$2	-$2,597	0.00%	$10,702	▨	▨	■	▨	■		■	▨		▨	■			■	
• Express Rt 1/128 to Boston via Route 1	2,473	1,944	49.5	3.2	87%	$3,660	$207	$1	$109	0.04%	$108	■		■	■	▨					▨				▨	
• Express Rt 3/128 to Boston via 128 and I-93	3,140	2,355	56.1	3.4	94%	$3,721	$207	$3	$56	0.04%	$137	■		■	▨	▨					▨				▨	
• Express Rt 3/128 to Alewife via Rts 128 and 2	2,473	2,047	79.8	3.6	98%	$3,036	$160	$1	$9	0.03%	$112	■		■	▨	▨					▨				▨	
• Improved Express Service in the Mass Pike Corrido	523	322	104.6	7.6	144%	$0	$0	$0	-$37	0.01%	$0			▨					▨		▨				▨	

Table F-2
Evaluation Criteria

	Utilization				Cost-Effectiveness					Air Quality Impacts		Service Quality and Coverage								Impact on System			Economic Impacts		Land Use Impacts	
	Total New Trips	New Transit Trips (Weekday)	Riders/Vehicle Service Hour	Riders/Vehicle Service Mile	Farebox Ratio	Investment/New Daily Transit User	Annualized Cost/New Daily Transit User	Annualized Cost/Hr of Travel Time Savings	Annual Operating Subsidy (000s)	% Emissions Reduction	Capital Cost/kg VOC Eliminated (000s)	Improved Connections	System Accessibility	Distribution of Service	Unmet Needs	Travel Time Savings	Safety/Security	Comfort/Convenience	Crowding	Preservation of Existing System	Preservation of Future Options	Efficiency/Effectiveness	Economic Development Potential	Potential for Private-Sector Participation	Supports Urban Core	Supports Suburban Compact Development
4. New Radial Services																										
F. Commuter Rail Extensions																										
• Ipswich Line: Ipswich to Newburyport**																										
Existing Line Improvements	2,150	1,463	71.7	0.6	72%	$25,427	$1,005	NA	$347	0.04%	$608															
Newburyport Extension Segment	1,638	1,438	43.0	1.4	75%	$59,527	$2,381	NA	$410	0.03%	$1,571															
Total	3,788	2,901	55.6	0.8	74%	$42,330	$1,687	$35	$756	0.07%	$1,062	▨			▨	▨				▨	▨				▨	▨
• Haverhill Line: Wakefield to Topsfield																										
Existing Line Improvements	4,056	1,924	2,385.9	-10.3	27%	$5,198	$174	NA	$2,543	NA	NA															
Topsfield Extension Segment	767	546	4.9	0.2	10%	$320,299	$13,806	NA	$2,810	NA	NA															
Total	4,823	2,470	30.6	1.2	19%	$74,851	$3,187	$48	$5,352	0.08%	$1,452	▨		▨	▨	■				▨	▨				▨	▨
• Haverhill Line: Haverhill to Plaistow NH																										
Existing Line Improvements	4,537	2,886	79.1	2.1	62%	$27,099	$1,061	NA	$891	NA	NA															
Plaistow Extension Segment	689	286	25.6	4.8	24%	$183,326	$7,314	NA	$891	NA	NA															
Total	5,226	3,172	62.0	2.2	40%	$41,185	$1,625	NA	$1,781	NA	NA	▨		▨	▨	▨				▨	▨				▨	▨
• Lowell Line: Lowell to Nashua, NH																										
Existing Line Improvements	5,759	3,198	140.8	2.3	99%	$10,664	$427	NA	$26	NA	NA															
Nashua Extension Segment	1,482	520	22.3	1.0	19%	$198,662	$6,835	NA	$2,345	NA	NA															
Total	7,241	3,718	67.4	1.8	49%	$36,958	$1,323	$3	$2,371	0.12%	$685	▨		▨	▨	■				▨	▨				▨	▨
• Framingham Line: Framingham to Worcester**																										
Existing Line Improvements	684	264	NA	NA	NA	NA	NA	NA	NA	NA	NA															
Worcester Extension Segment	6,012	3,204	36.2	1.1	63%	$74,260	$2,660	NA	$2,538	NA	NA															
Total	6,696	3,468	40.3	1.2	65%	$68,607	$2,457	$13	$2,538	0.10%	$1,452					■										
• Framingham Line: Framingham to Marlborough																										
Marlboro Extension	1,632	774	8.3	0.3	9%	$190,181	$10,408	$63	$7,759	0.04%	$2,334	▨		▨	▨	▨				▨	▨				▨	▨
• Franklin Line: Forge Park/495 to Milford																										
Existing Line Improvements	1,928	930	-275.4	14.0	-227%	$98,529	$4,372	NA	-$928	NA	NA															
Milford Extension Segment	383	83	7.2	0.7	7%	$674,048	$45,566	NA	$2,144	NA	NA															
Total	2,311	1,013	50.2	3.5	40%	$145,684	$7,747	$111	$1,216	0.03%	$3,212	▨		▨	▨	▨				▨	▨				▨	▨
• Franklin Line: Walpole to Foxborough																										
Existing Line Improvements	1,538	810	32.9	0.6	22%	$33,444	$1,338	NA	$1,479	NA	NA															
Foxborough Segment	38	8	1.8	0.1	1%	$3,526,050	$138,000	NA	$900	NA	NA															
Total	1,576	818	23.3	0.5	15%	$67,602	$2,675	$35	$2,379	0.02%	$1,368	■		▨	▨	▨				▨	▨				▨	
G. Other New Commuter Rail Services																										
• New Bedford/Fall River Lines	6,465	2,820	25.4	0.6	22%	$204,255	$5,436	NA	$9,558	0.10%	$3,457	▨		▨		▨				▨	▨		▨		▨	
• New Mills Line	1,823	855	14.3	0.6	22%	$156,089	$6,498	$51	$4,364	0.03%	$2,386	▨		▨	▨	▨				▨	▨				▨	▨
• Additional Service to Dedham Corporate Center	630	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	▨									▨				▨	

Table F-2
Evaluation Criteria

	Utilization				Cost-Effectiveness					Air Quality Impacts		Service Quality and Coverage								Impact on System			Economic Impacts		Land Use Impacts	
	Total New Trips	New Transit Trips (Weekday)	Riders/Vehicle Service Hour	Riders/Vehicle Service Mile	Farebox Ratio	Investment/New Daily Transit User	Annualized Cost/New Daily Transit User	Annualized Cost/Hr of Travel Time Savings	Annual Operating Subsidy (000s)	% Emissions Reduction	Capital Cost/kg VOC Eliminated (000s)	Improved Connections	System Accessibility	Distribution of Service	Unmet Needs	Travel Time Savings	Safety/Security	Comfort/Convenience	Crowding	Preservation of Existing System	Preservation of Future Options	Efficiency/Effectiveness	Economic Development Potential	Potential for Private-Sector Participation	Supports Urban Core	Supports Suburban Compact Development
5. Suburban Circumferential Movement																										
A. Route 128 Circumferential Bus Service	3,474	3,474	12.0	0.7	16%	$4,552	$382	NA	$3,962	0.05%	$179	■		▨	▨						▨					
B. Feeder Bus to Rapid Transit at Riverside	690	490	14.4	NA	17%	$5,510	$459	$35	$659	0.01%	$141	■			▨			▨			▨				▨	▨
C. Feeder Bus to Commuter Rail in Needham	340	0	16.9	NA	0%	NA	NA	NA	$113	0.00%	NA	▨									▨				▨	▨

Key:

☐ = no improvement, no likely impact, or negative impact

▨ = small improvement or small positive impact

■ = significant improvement; or possible large postive impact

L= low or negligible effect
NA= not applicable or not available
**= required by amendments to the State Implementation Plan/Central Artery agreement

Cost-Effectiveness

- Farebox Ratio This figure, which equals fare revenue divided by the operating cost, shows the cost-effectiveness of a project in terms of how much of the operating cost would be recovered through fare revenue. The service being examined can be compared to existing service on this basis. This measure only addresses the cost of operating the service and does not take into account the cost of constructing it.

- Investment/New Daily Transit User This figure represents the total capital cost of a project divided by the total number of individuals[3] that would be drawn to the transit system (out of automobiles) by the new service.

- Annualized Cost/New Daily Transit User This figure provides a measure of the total cost of the project (operating and capital) on an annual, ongoing basis per individual diverted from private automobiles. It is a measure of the cost of attracting new riders.

- Annualized Cost/Hour of Travel Time Savings This figure provides a measure of the total cost (operating and capital) per hour of travel time saved by existing riders. It is a measure of the benefit of the project to existing riders.

- Annual Operating Subsidy This figure represents the annual increase in operating subsidies (not including debt service) that would be required to operate the new service. It equals the operating cost of the project minus fare revenues that would be generated.

Air Quality Impacts

- Percent Emissions Reduction This figure represents the percent reduction of regional volatile organic compound emissions resulting from the project and the ridership it attracts.

- Capital Cost/Kg of VOC Eliminated This figure represents the capital cost to eliminate one kilogram of VOC per weekday. It measures how cost-effective these projects are as measures to improve regional air quality.

Service Quality and Coverage

Most measures of service quality and coverage are subjective in nature. Certain characteristics could be quantified, but in most cases, subjective judgments were made based on a consensus judgment of the PMT Working Committee.

- Better Connections (Intermodalism) Improved connections between modes and transit services would attract new transit riders and benefit existing riders. As such, some of the benefits of these projects are addressed through the cost-effectiveness measures described above. However, one of the key goals of ISTEA is to promote the integration of various components of the transportation system. It is also one of the policies from the Phase 2 report that is guiding Phase 3 efforts.

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[3] The number of individuals was approximated by dividing total ridership by two.

Examples of projects that would provide better connections would be the Red–Blue Connector, the North Station-South Station Rail Link, improved roadway, pedestrian, and bicycle access to stations, new Logan services, and additional park-and-ride facilities.

In this category, a judgment was made on whether the new service improved connections in terms of (1) no improvement, (2), small improvement, and (3) significant improvement.

- System Accessibility All new projects must meet the requirements of the Americans with Disabilities Act (ADA). However, some projects may have additional benefits beyond accessibility of the individual project (for example, what would be the impact on accessibility of replacing much of the existing Somerville bus service with a Green or Blue line extension to Medford Hillside?) The impact of these types of changes was rated in three categories: (1) no improvement or negative impact, (2), small improvement, and (3) significant improvement.

- Distribution of Service Would there be an equitable distribution of service, and would there be improved service to transit dependent populations? Judgments were made based on characteristics of specific areas such as the amount of transit service relative to total population and population density, transit miles to highway miles, route miles per town, etc.

- Unmet Needs Based on whether or not one or more unmet needs could be identified that would be served, a judgment was made of: (1) no improvement, (2), small improvement, and (3) significant improvement.

- Travel Time Savings A major impact of reducing in-vehicle travel times and eliminating transfers is that service is improved for existing riders. This impact is reflected in "Total Travel Time Savings" figure. However, the total does not show the benefit on a per passenger basis, thus making it difficult to use this figure to determine the benefit relative to other projects. To determine the relative benefits of decreasing travel times, the travel time savings per existing trip was calculated. From the resulting per trip figures, a judgment was made of (1) no improvement, (2), small improvement, and (3) significant improvement based on relative differences.

  For example, a Green Line extension of Medford Hillside would save 1,161 hours of travel time each weekday for those who now make bus trips. For the 7,900 riders that would shift from buses to the Green Line, each would save an average of nine minutes per trip. This nine minute figure can be compared to the equivalent figure for other projects.

- Safety/Security Few, if any of the projects examined were aimed specifically at safety or security. This instead was a secondary impact, with a judgment made of (1) no improvement, (2), small improvement, and (3) significant improvement.

- Comfort/Convenience As with safety and security, few, if any of the projects were aimed specifically at improving convenience and/or comfort. This also was a secondary impact, with a judgment made of (1) no improvement, (2), small improvement, and (3) significant improvement.

- Crowding Impacts of the new service on crowding on other services were identified (for example, the reduction in Green Line Central Subway crowding that would result from a Blue Line to Riverside). From this, a judgment was made of (1) no improvement, (2), small improvement, and (3) significant improvement.

Impact on Existing System

Three criteria were used for this area, each with ranking categories of (1) negative impact, (2) no impact, or (3) positive impact:

- Preservation of Existing System Projects that would help preserve the existing system could fall into a number of categories, such as station modernization, track upgrades, equipment purchases, etc.

- Preservation of Future Options This would include projects such as purchase of abandoned rights-of-ways, construction of facilities designed to accommodate future expansion, etc.

- Efficiency/Effectiveness This would include projects that allowed an existing service to be operated more efficiently, that shifted ridership away from an overcrowded service, etc.

Economic Impacts

- Economic Development Potential Assessments of economic impacts reflect judgments based upon the type of service and the area served: (1) no likely impact (2), small positive impact, and (3) possible large positive impact.

- Potential for Private-Section Participation Assessments of potential for private-sector involvement were subjective, with judgments made based upon the type of service and the area served: (1) not likely (2), possible, and (3) likely. The private-sector involvement considered in this category would be beyond typical involvement such as design and construction.

Land Use Impacts

There are a number of differing perspectives on how transportation facilities and services should guide and/or reflect land use. MAPC's MetroPlan 2000 sets forth a regional plan that encourages compact development and discourages "sprawl" development. The relevant policies set forth in the PMT Phase 2 report are that new transportation services should "encourage development in the urban core" and that "support compact development." These policies are generally consistent with the goals of MetroPlan 2000, although there can be differences of opinion as to which of the two policies is more important and how the two are interpreted (for example, a commuter rail extension that encourages urban core development can be viewed as discouraging compact development in the suburbs). Given existing differences in opinion, the projects were evaluated separately on their effects on the urban core and on compact development in the suburbs. The impacts were assessed as (1) does not support, (2) supports moderately, and (3) supports strongly.

Appendix G
Project Results

This appendix presents a description of each project examined in the PMT, as well as a discussion of each project's ridership, cost, air quality, and other impacts, and the conclusions that were reached as to each project's merit. As described in Appendix F, the examination of projects consisted of the determination of projected ridership project in 2020, operating and capital costs, fare revenue, and service, traffic and air quality impacts. Each project was then evaluated based on a number of measures addressing utilization, cost-effectiveness, and a number of financial, air quality, and other impacts.

Note that projects were analyzed at level of detail appropriate for systems level planning. The objective was to identify the projects that would generate new ridership and air quality benefits in a cost-effective manner and be worthy of further, more in-depth study. Most of the projects recommended in the PMT would require environmental impact and alternatives analysis before they can proceed to design and construction.

It is also important to note that ridership projections are for the year 2020 and depend, to some extent, on growth in population and employment. If these projects were built tomorrow, they would not achieve the ridership levels forecast by the regional model because the projected growth has not yet occured. Operating costs, on the other hand, are presented in 1991 dollars, fare revenue figures are based on current (1993) fare levels, and capital costs are in 1993 dollars. Implicit within the use of these figures is the assumption that costs and fare revenue will increase at the same rate as inflation. Costs could rise faster or slower than inflation depending on the wage rate, labor agreements, changes in technical efficiencies in both construction and operations, and future fare increases.

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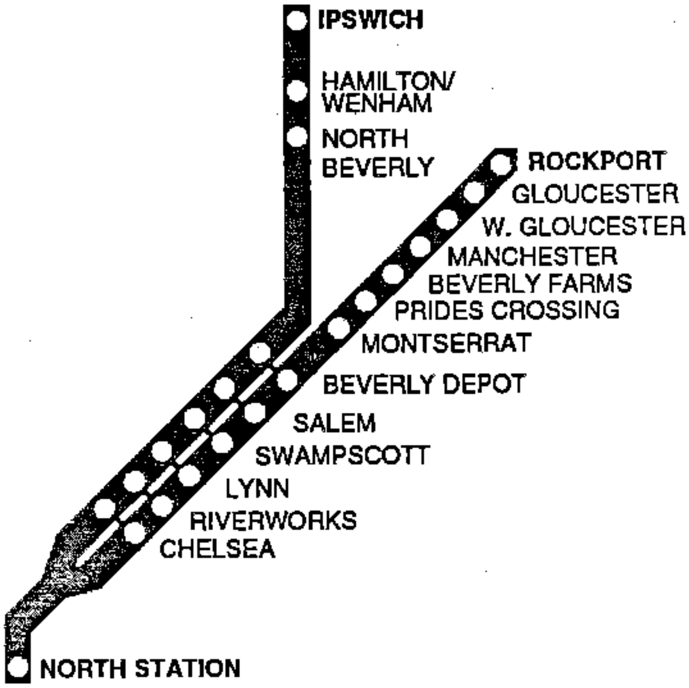
Rockport/Ipswich Line Improvements

Existing Service

Currently, the two branches of the Rockport/Ipswich Line serve 17 stations (see Figure G-1). During the AM peak, three inbound trains on the Rockport branch provide service at 25 to 104 minute headways, and four trains on the Ipswich branch provide service at 30 to 50 minute headways. One train also operates inbound from Beverly Depot. Most peak-period Ipswich branch trains stop at all intermediate stations, but some Rockport branch trains run express south of Salem. Service is relatively frequent at stations served by trains from both branches—Beverly Depot, Salem, Swampscott, Lynn, and Chelsea—with headways of less than 30 minutes.

Figure G-1
Existing Rockport/Ipswich Line Service



PM peak outbound service generally mirrors AM peak inbound service. (Riverworks is a private station restricted to use by workers at the General Electric complex in West Lynn. About half of all weekday trains in each direction stop there.) During off-peak periods, headways average approximately two hours on both branches.

PMT Alternatives

For the PMT analysis, two service improvement alternatives were examined:

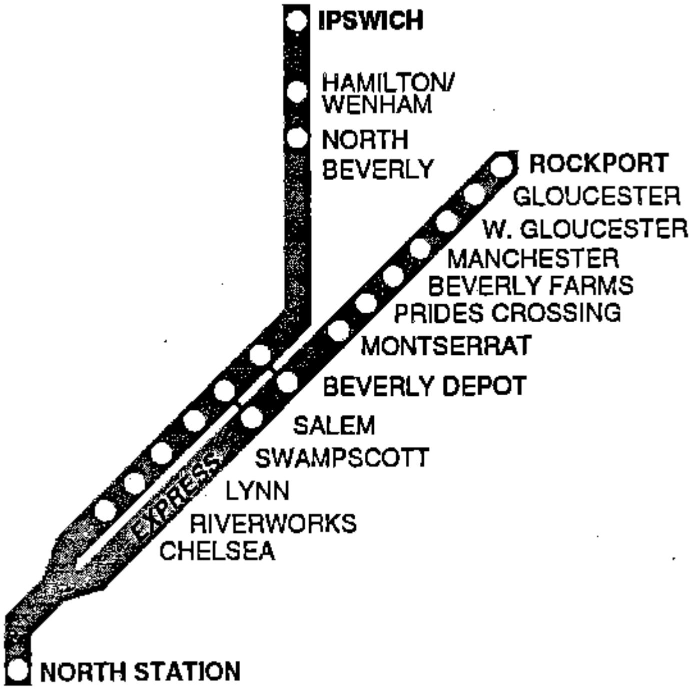
1. A combination of faster running times and express service on the existing line.
2. An extension to Newburyport, combined with faster running times and express service on the Rockport branch.

1. Faster Running Times with Rockport Express Service

The first alternative involves service improvements to the existing line. These include track and right-of-way improvements to increase the maximum operating speed to 70 mph, the operation of peak-period express trains on the Rockport branch, and increases in service levels.

During peak periods, Rockport trains would make all stops from Rockport to Salem (see Figure G-2), and then run express to North Station. Ipswich trains would make all stops from Ipswich to North Station, and would provide all service to stations on the shared line south of Salem. Passengers making interzone trips from Rockport branch stations north of Beverly to stations south of Salem would transfer at Beverly Depot or Salem. Peak period service on both branches would be operated at 30 minute headways. This service configuration would provide 15-minute headways at Beverly and Salem, and 30-minute headways at all other stations. Compared to current operations, service would be more frequent at all stations on both branches from Salem northward, and slightly less frequent at Swampscott, Lynn, and Chelsea.[1]

Figure G-2
Express/Local Service Configuration



For purposes of analysis, it was assumed that existing service patterns would be retained during off-peak hours.

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[1] From Lynn, when relative access times to express bus routes and commuter rail are considered, express buses provide shorter total travel time than commuter rail. For this reason, an increase in service at Lynn station was not deemed to be necessary.

Alternative 1 service with higher maximum speeds and express trains would reduce travel times by five to eight minutes for most trips, or by nine to 42 percent on express trains, and up to 23 percent on local trains (see Tables G-1 and G-2).

Table G-1
Faster Rockport/Ipswich Line Service:
Rockport Branch Travel Times to North Station (in minutes)

	Existing Service	Future Express
Rockport	66	58
Gloucester	58	52
W. Gloucester	53	48
Manchester	47	41
Beverly Farms	42	36
Prides Crossing	40	33
Montserrat	35	28
Beverly Depot	30	24
Salem	25	18

Table G-2
Faster Rockport/Ipswich Line Service:
Ipswich Branch Travel Times to North Station (in minutes)

	Existing Service	Future Local
Ipswich	55	50
Hamilton/Wenham	48	43
N. Beverly	44	39
Beverly Depot	37	34
Salem	33	28
Swampscott	26	22
Lynn	23	19
Riverworks	20	15
Chelsea	12	7

2. Newburyport Extension (with Faster Running Times and Express Service)

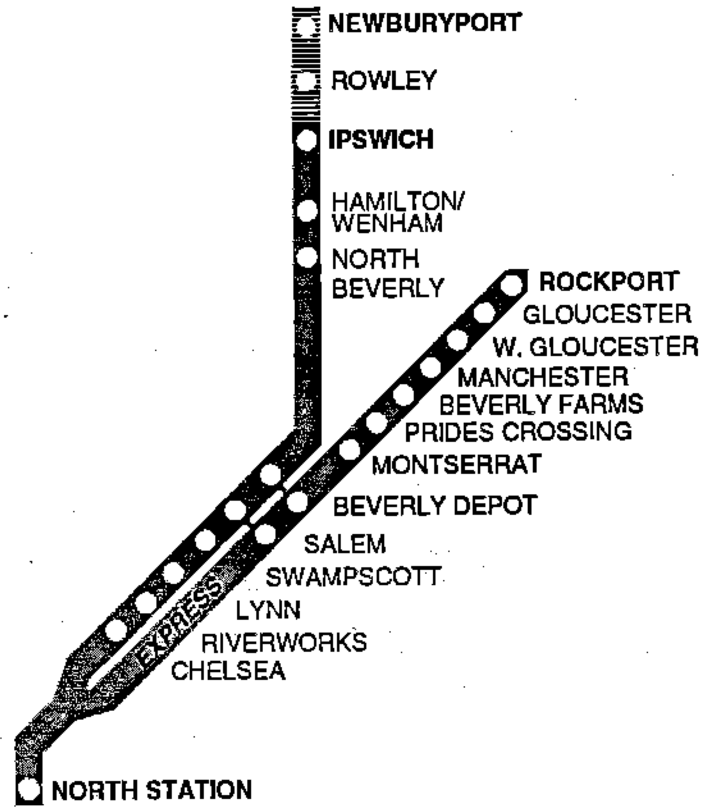
The second alternative involves a 9.6 mile extension of service from Ipswich to Newburyport, and the running time and express service improvements of Alternative 1. The alignment would be the former Boston & Maine Railroad Eastern Route Main Line, along which service is currently abandoned. There would be two stations on the extension: one in Rowley and the new terminal in Newburyport. Rowley would be in Zone 7 and Newburyport in Zone 8. Parking would be provided at both stations.

During peak periods, Rockport trains would make all stops from Rockport to Salem and then run express to North Station. Newburyport trains would make all stops from Newburyport to North Station, and would provide all service to stations on the shared line south of Salem (see Figure G-3).

Peak-period service on both branches would operate at 30 minute headways. During off-peak periods, existing schedules would be retained, except that all Ipswich trains would be extended to Newburyport.

Travel times from existing stations to North Station would be the same as in Alternative 1 (and as shown in Tables G-1 and G-2). The travel time from Newburyport would be 62 minutes, and the travel time from Rowley would be 55 minutes.

Figure G-3
Extension to Newburyport w/Rockport Express Trains



Ridership Impacts

Faster service, including the operation of express trains, would increase ridership on the present Rockport/Ipswich Line by 2,150 trips per weekday. Of these, 1,463, or 68 percent, would be new transit trips (see Table G-3). The Newburyport extension would attract fewer new riders (1,638 per weekday), but a similar number of new transit trips (1,438):

Newburyport:	1038
Rowley:	600
Total	1,638

Table G-3
Ridership Impacts of Rockport/Ipswich Line Improvements

	Total Trips	New Transit Trips
Existing Line Improvements	2,150	1,463
Newburyport Extension	1,638	1,438
Total	3,788	2,901

For comparison, ridership at Newburyport would be higher than current ridership at existing Ipswich branch stations north of Beverly (250 to 600 trips per weekday). Rowley ridership would be similar to that at Ipswich and Hamilton/Wenham, but higher than at North Beverly.

Costs and Cost-Effectiveness

The tracks on the existing Rockport/Ipswich Line are in generally good condition, but the state Department of Public Utilities (DPU) has imposed a number of speed restrictions at at-grade crossings. To operate service at higher speeds, crossing protection would need to be improved at six intersections at a cost of approximately $1.5 million. In addition, two new train sets would be required to operate faster service with express trains on the Rockport branch ($17.1 million for two locomotives and 12 cars). This would increase the total cost to $18.6 million (see Table G-4).

Table G-4
Costs of Rockport/Ipswich Line Improvements

	Operating Cost (Annual)	Fare Revenue (Annual)	Capital Cost	Capital Cost/ New Trip
Existing Line Improvements	$1.2m	$0.9m	$18.6m	$12,700
Newburyport Extension	$1.7m	$1.3m	$42.8m[2]	$29,800

The extension from Ipswich to Newburyport would cost $20.8 million to $30.6 million for track, signals, the two stations, and a layover facility (the right-of-way is already owned by the MBTA). In addition, two new train sets would be required to operate service along the extension, at a cost of $17.1 million. This would increase the total cost to $37.9 million to $47.7 million.

Existing line improvements would increase operating costs by $1,217,000 per year. Increased fare revenue, at $870,000 per year would cover 71 percent of this. The Newburyport extension would increase operating costs by an additional $1.7 million per year, of which $1.25 million, or 75 percent, would be funded by increased fare revenue.

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[2] The Environmental Notification Form (ENF) for the Newburyport extension estimates capital costs, exclusive of rolling stock, at $18.5 to $27.3 million in 1989 dollars. The figure used here, and in subsequent calculations, represents the mid-point of this estimate inflated to 1993 dollars, plus the cost of the additional locomotives and coaches required.

The capital cost per new transit rider of $12,700 for the existing line improvements is low compared to other rail projects. The $29,800 cost per new transit rider for the Newburyport extension is in the mid-range of costs for rail projects.

Air Quality Impacts

Improvements to the existing line, and the Newburyport extension would each reduce regional emissions by 0.035 percent, for a total reduction of 0.07 percent. The capital cost per kilogram of VOC eliminated per day would be $608,300 for existing line improvements, and $1.6 million for the extension (see Table G-5). The costs of the existing line improvements per air quality benefit received is low in comparison to other PMT projects (with the only exceptions being existing line improvements on the Lowell and Haverhill/Reading lines). The cost of the air quality benefits for the Newburyport extension falls in the mid-range of the comparable costs for other PMT projects.

Table G-5
Air Quality Impacts of Rockport/Ipswich Line Improvements

	% Reduction Regional Emissions	Capital Cost/kg of VOC Elim/weekday
Existing Line Improvements	0.035%	$608,300
Newburyport Extension	0.035%	$1,571,000

Conclusions

Both existing line improvements and a Newburyport extension would perform relatively well in ridership, operating costs, fare revenue, and air quality benefits in the year 2020.

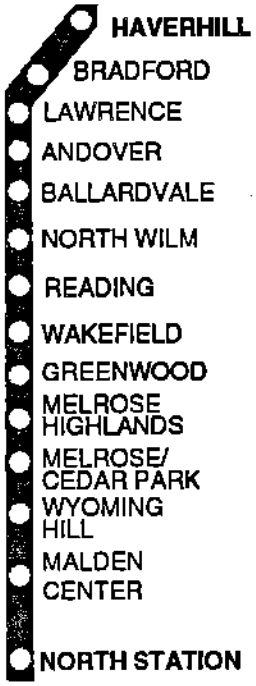
For improvements to the existing Rockport/Ipswich Line, the capital costs per new transit rider ($12,700) and per kilogram of weekday VOC elimination ($608,300) would be lower than those of most other PMT rail projects. For the Newburyport extension, the same measures ($29,800 and $1.6 million, respectively) would fall in the mid-range for PMT rail projects.

Haverhill/Reading Line Improvements

Existing Service

Currently, the Haverhill/Reading Line serves 14 stations (see Figure G-4). During the AM peak, five of seven inbound trains operate the full distance of the line from Haverhill to North Station; the other two operate only from Reading.[3] Headways from Haverhill range from 24 to 57 minutes; those from Reading range from 20 to 36 minutes. In the PM peak, three of six outbound trains operate to Haverhill, while the other three terminate at Reading. Headways to Haverhill are 45 to 60 minutes, and headways to Reading are 15 to 45 minutes.

Figure G-4
Existing Haverhill/Reading Line Service



Most off-peak and non-peak direction trains operate only between Reading and North Station (23 of 31 trains).[4] Off-peak service to and from Reading operates at approximately 30 to 90 minute headways.

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[3] One of these two trains has bus connections from all stations north of Reading except North Wilmington.

[4] Two outbound off-peak trains have bus connections to all stations north of Reading except North Wilmington.

PMT Alternatives

For the PMT analysis, three service improvement alternatives were examined:

1. A combination of faster running times, increased service levels, and express service on the existing line.
2. An extension to Plaistow, New Hampshire, combined with faster running times, increased service levels and express service.
3. Service to Topsfield, which would be operated as a branch of the Haverhill/Reading Line, combined with faster running times, increased service levels, and express service on the existing line to Haverhill.

1. Faster Running Times, Increased Service Levels, and Express Service

The first alternative involves service improvements to the existing line. These include track and right-of-way improvements to increase the maximum operating speed to 70 mph, the operation of increased levels of service, and peak period express trains.

During peak periods, express trains would serve Haverhill, Bradford, Lawrence, Andover, Reading, Wakefield, and Malden Center stations. Local trains would make all stops between Haverhill and North Station (see Figure G-5). Express and local trains would both operate at 30 minute headways. This would result in 15 minute headways at stations served by express trains, and 30 minute headways at all others. Compared to current operations, service frequencies would be similar at stations from Wyoming Hill to Reading, but much more frequent north of Reading.

During off-peak periods, present schedules would be retained.

Under this alternative, travel times would be reduced by 14 to 24 minutes, or by 34 to 54 percent on express trains, and by 10 to 36 percent on local trains (see Table G-6).

It should be noted that the operating plan used in analysis of the North-South Rail Link assumed a significantly different strategy for the Reading/Haverhill Line. Under that strategy, service on the southern end of the line would run only between Boston and North Wilmington. All service to stations between Ballardvale and Haverhill would be provided by trains running via the Lowell Line to Wilmington and the Wildcat Branch to Wilmington Junction. (One weekday off-peak train in each direction now uses this route.) This strategy was dictated primarily by operating constraints related to phasing in of system electrification.

Figure G-5
Express/Local Service Configuration w/o Extension

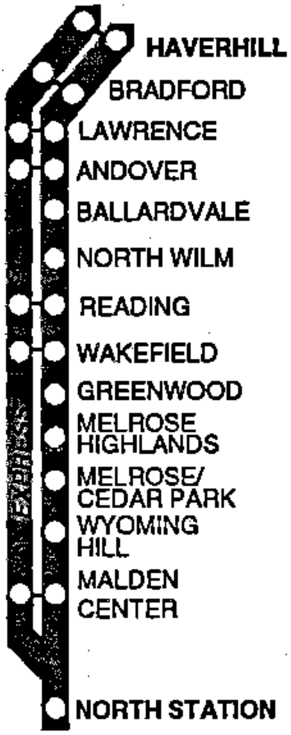


Table G-6
Faster Haverhill/Reading Line Service: Travel Times to North Station (in minutes)

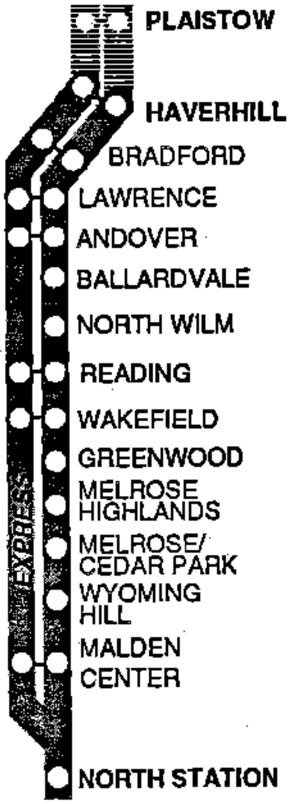
	Existing Service	Future Local	Future Express
Haverhill	68	61	45
Bradford	66	59	42
Lawrence	57	50	34
Andover	52	45	28
Ballardvale	48	40	—
N. Wilmington	41	34	—
Reading	32	28	16
Wakefield	26	23	12
Greenwood	23	20	—
Melrose Highlands	20	16	—
Melrose-Cedar Park	18	14	—
Wyoming Hill	16	11	—
Malden Center	11	7	—

2. Plaistow Extension

The second alternative involves the same improvements as Alternative 1, plus a 3.6 mile extension of service from Haverhill to Plaistow, New Hampshire. There would be one station, which would be the new terminal at Plaistow. Plaistow Station would have 500 parking spaces and be in Zone 8.

During peak and off-peak periods, service would operate in the same manner as in Alternative 1, but all Haverhill trains would be extended to Plaistow (as shown Figure G- 6). During peak periods, both express and local trains would operate at 30-minute headways. During off-peak periods, only local service would be operated.

Figure G-6
Express/Local Service Configuration w/ Plaistow Extension



Travel times from existing stations to North Station would be the same as in Alternative 1 (and as shown in Table G-6). The travel time between Plaistow and North Station would be 52 minutes on express trains and 68 minutes on local trains.

3. Topsfield Extension

An extension to Topsfield would consist of a 14.7-mile branch off the present Haverhill/Reading Line from Wakefield Junction, north of Greenwood Station, through Lynnfield, Peabody, and Danvers, to Topsfield. The entire route is within the MBTA District. The alignment would be the former Boston & Maine Corporation Newburyport Branch, which is owned by the MBTA.

Figure G-7
Service Configuration with Topsfield Branch

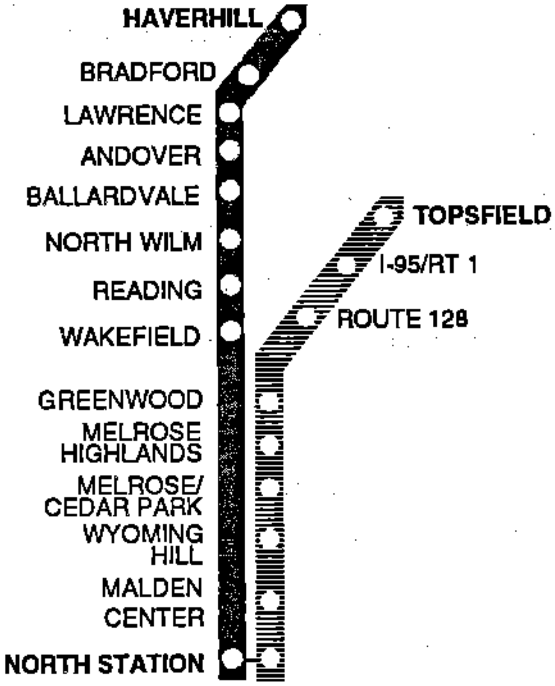


Table G-7
Topsfield Service: Travel Times to North Station (in minutes)

Haverhill/Reading Branch		Topsfield Branch	
Haverhill	52		
Bradford	47		
Lawrence	39		
Andover	33		
Ballardvale	28		
N. Wilmington	22	Topsfield	41
Reading	16	I-95/Route 1	31
Wakefield	12	Route 128	24
Greenwood	—	Greenwood	20
Melrose Highlands	—	Melrose Highlands	16
Melrose-Cedar Park	—	Melrose-Cedar Park	14
Wyoming Hill	—	Wyoming Hill	11
Malden Center	—	Malden Center	7

There would be three stations on the extension: (1) at Route 128 in Wakefield, (2) near the intersection of I-95/Route 1 in Peabody, and (3) the terminal at Route 1 in Topsfield. Five hundred parking spaces would be provided at each station. Topsfield would be in Zone 5, I-95/Route 1 in Zone 4, and Route 128 in Zone 2.

During peak periods, a combination of express and local trains would be run (see Figure G-7). Express and local trains would each run at 30 minute intervals, with travel times as shown in Table G-7. Trains originating in Haverhill would stop at Haverhill, Bradford, Lawrence, Andover, Ballardvale, North Wilmington, Reading and Wakefield, and then operate express to North Station. Local service would run between Topsfield and North Station. During off-peak hours present schedules would be retained, but Topsfield service would be added with about the same number of trains as Haverhill.

Ridership Impacts

Higher speeds and the operation of express trains on the existing Haverhill/Reading Line would increase year 2020 ridership by 4,540 trips per weekday. Of these, 2,890 (64 percent) would be new transit trips (see Table G-8). These increases would be the largest attainable on any line through the operation of faster service and express trains.

Table G-8
Ridership Impacts of Haverhill/Reading Line Improvements

	Total Trips	New Transit Trips
Alternative 1 (No Extension)		
Existing Line Improvements	4,540	2,890
Alternative 2 (Plaistow Extension)		
Existing Line Improvements	4,540	2,890
Plaistow Extension	690	290
Total	5,230	3,170
Alternative 3 (Topsfield Extension)		
Existing Line Improvements	4,060	1,920
Topsfield Extension	770	550
Total	4,820	2,470

The Plaistow extension would attract low total ridership (690 trips per weekday), and few new trips (290 per weekday).[5]

The Topsfield extension would also attract very low ridership—only 770 trips at all three stations combined. On a station-by-station basis, Topsfield extension ridership would be among the lowest in the commuter rail system. The Route 128 station in Wakefield would serve the largest share of riders on the extension (340) followed by I-95/Route 1 (220). Topsfield Station would serve the fewest riders (210).

Costs and Cost-Effectiveness

The Haverhill/Reading Line has a mix of single and double track. Despite some scheduling constraints, the assumed increases in service could be accommodated. A more significant operating constraint on this line is imposed by closely spaced grade crossings in Melrose and

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[5] These estimates are based on the "Draft Report, Ridership Potential: Plaistow, NH – Boston, MA Commuter Rail Service" prepared by Frederic R. Harris, Inc., for the Rockingham [NH] Regional Planning Council, November 1992.

Wakefield. At these crossings, the Department of Public Utilities (DPU) limits train speeds to 30 mph (in Melrose) and 15 mph (in Wakefield). Upgrading crossing protection to permit higher speeds would cost up to $5.0 million, and would still require DPU approval. In addition, four new train sets would be required to operate the increased service levels and faster service with express trains, at a cost of $34.1 million (for four locomotives and 24 cars). This would increase the total cost to $39.1 million (see Table G-9).

Table G-9
Costs of Haverhill/Reading Line Improvements

	Operating Cost (Annual)	Fare Revenue (Annual)	Capital Cost	Capital Cost/ New Trip
Alternative 1				
Existing Line Improvements	$2.3m	$1.4m	$39.1m	$13,600
Alternative 2 (Plaistow Extension)				
Existing Line Improvements	$2.3m	$1.4m	$39.1m	$13,600
Plaistow Extension	$1.2m	$0.3m	$26.2m	$91,700
Total	$3.5m	$1.7m	$65.3m	$20,600
Alternative 3 (Topsfield Extension)				
Existing Line Improvements	$3.5m	$1.0m	$5.0m	$2,600
Topsfield Extension	$3.1m	$0.3m	$87.4m	$160,100
Total	$6.6m	$1.3m	$92.4m	$37,400

The extension from Haverhill to Plaistow would cost $17.7 million for track, signals, a new station at Plaistow, and a layover facility.[6] One additional train set would be required to operate service along the extension, which at $8.5 million, would raise the total cost to $26.3 million. The capital cost per new rider would be $91,700, making it one of the less cost-effective PMT projects.

The extension to Topsfield would cost $53.3 million for track, signals, three new stations with parking, and a layover facility. Four train sets would be needed to operate Topsfield service, at a cost of $34.1 million, bringing the total cost of the extension to $87.4 million. The capital cost per new rider would be $160,100. In this measure, the extension would be among the most costly projects examined for the PMT.

Existing line improvements would increase operating costs by $2.3 million per year, of which 61 percent ($1.4 million) would be generated in increased fare revenue. The Plaistow extension would increase operating costs by $1.2 million per year, but would generate only 25 percent of these costs in fare revenue ($0.3 million). The Topsfield extension would perform even more poorly, increasing operating costs by $3.1 million, while generating only $0.3 million in fare revenue (only ten percent of costs).

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[6] The route between Plaistow and Haverhill is the same one that would be used by proposed Amtrak intercity service from Boston to Portland. The same upgrading of track and signals required for Plaistow commuter service is also needed for Portland service, but appropriate cost allocation and funding for the latter project is still under discussion.

Air Quality Impacts

Improvements to existing Haverhill/Reading Line service would reduce regional emissions by 0.10 percent (see Table G-10). This is among the largest air quality benefits for improvements to an existing service. The capital cost per kilogram of VOC eliminated per day for Haverhill/Reading Line improvements would be $484,800. This is low compared to most other rail improvements.

Table G-10
Air Quality Impacts of Haverhill/Reading Line Improvements

	% Reduction Regional Emissions	Capital Cost/kg of VOC Elim/weekday
Existing Line Improvements	0.10%	$484,800
Plaistow Extension	NA	NA
Topsfield Extension	<0.01%	NA

Ridership estimates for the Plaistow extension were derived for a study done for the Rockingham Regional Planning Council; this study did not include estimates of air quality benefits. Nevertheless, based on the small number of new transit trips attracted, and the short length of the extension, it can be reasonably assumed that air quality benefits would be very small.

Air quality benefits for the Topsfield extension would also be very small, because of the small ridership increase. The extension would reduce regional emissions by less than 0.01 percent.

Conclusions

Service improvements on the existing Haverhill/Reading Line (operation of more frequent trains to and from Haverhill, faster operating speeds, and operation of express trains) would increase ridership by 4,540 trips per weekday in the year 2020. This would include diversions of 2,890 trips from automobiles. Both of these numbers are high compared to those for other improvements to existing services. The reduction in regional emissions, at 0.10 percent, is also relatively high. The service improvements would also raise the overall ratio of revenues to operating costs for the line. For these improvements, the capital costs per new transit rider ($13,600) and per kilogram of weekday VOC elimination ($484,800) would be lower than those of most other PMT rail projects.

Either of the extensions—Plaistow or Topsfield—would attract few new riders and provide few air quality benefits. The costs of these extensions, both operating and capital, would be very high compared with the benefits received.

Lowell Line Improvements

Existing Service

Currently, the Lowell Line serves eight stations: Lowell, North Billerica, Wilmington, Mishawum, Winchester Center, Wedgemere, West Medford, and North Station. (There is also a private station between Winchester and Mishawum for reverse commuting to the Lechmere department store warehouse. Two outbound AM peak and three inbound PM peak trains stop there on request.) Service generally operates at 30 minute headways during peak periods and at 60 minutes during off-peak periods.

PMT Alternatives

For the PMT analysis, two service improvement alternatives were examined:

1. A combination of faster running times and express service on the existing line.
2. An extension to Nashua, combined with faster running times and express service.

1. Faster Running Times and Express Service on the Existing Line

The first alternative involves service improvements to the existing line. These include increasing the maximum operating speed to 70 mph, operating express trains during peak periods, and doubling service from Mishawum Station.

Peak-period express trains would provide service from Route 128 and beyond, making all stops from Lowell to Mishawum (Lowell, North Billerica, Wilmington, and Mishawum), and then running non-stop to North Station (see Figure G-8). Peak-period local trains would operate between Mishawum and North Station, and provide service to Mishawum, Winchester, Wedgemere, and West Medford. Peak-period local and express trains would both run on 30-minute headways. Frequencies would be similar to the present ones at all stations except Mishawum, where service would be doubled. Passengers making interzone trips from stations north of Route 128 to stations south of Route 128 would transfer at Mishawum. During off-peak periods, local service would continue to operate in its present fashion.

The operation of express trains and 70 mph maximum speeds would reduce travel times significantly—from 33 to 50 percent on express trains, and up to 23 percent on local trains.

Figure G-8
Express/Local Service Configuration

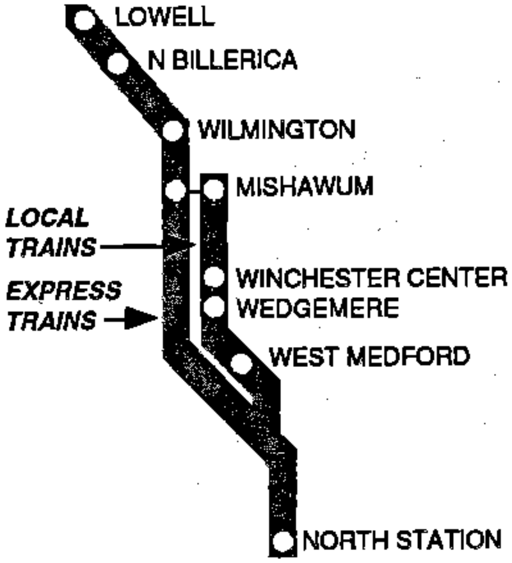


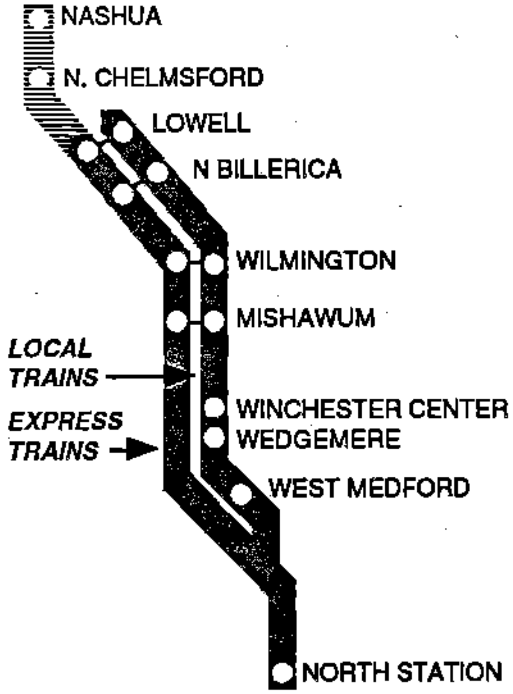
Table G-11
Faster Lowell Line Service: Travel Times to North Station (in minutes)

	Existing Service	Future Express	Future Local
Lowell	49	33	—
N. Billerica	41	27	—
Wilmington	32	19	—
Mishawum	26	13	20
Winchester	19	—	14
Wedgemere	16	—	12
W. Medford	12	—	8

2. Extension to Nashua with Faster Running Times and Express Service

The second alternative involves service improvements to the existing line and a 9.2 mile extension to Nashua, New Hampshire. There would be two stations on the extension: one in North Chelmsford and one in Nashua. The Nashua station would be near the Pheasant Lane Mall, about one quarter mile beyond the Massachusetts state line (see Figure G-9). The North Chelmsford station would be in Zone 6 (the same zone as Lowell); Nashua would be in Zone 8. Both stations would have parking (150 spaces in North Chelmsford and 500 at Nashua).

Figure G-9
Nashua Extension w/Express Trains



The alignment would be the former Boston & Maine Railroad New Hampshire Route Main Line. Between Lowell Station and the New Hampshire border, the right of way is now owned by the MBTA. The remainder is owned by the Boston & Maine Corporation, a subsidiary of Guilford Transportation Industries. Freight service is operated on the line by another Guilford subsidiary, the Springfield Terminal Railway Company.

The associated service improvements would be the similar to those of the first alternative in that maximum operating speeds would be increased to 70 mph and express trains would be operated. The express trains would stop at all stations at and beyond Route 128 (including North Chelmsford and Nashua), and then run express to North Station. Local trains would operate between Lowell and North Station, making all stops in between (as opposed to only between Mishawum and North Station in Alternative 1).

Local and express trains would both operate at 30 minute headways. This would mean that the Nashua, North Chelmsford, Winchester, Wedgemere, and West Medford stations would be served by trains departing every 30 minutes; Lowell, North Billerica, Wilmington, and Mishawum would be served by trains departing every 15 minutes. Only interzone passengers with one trip end in Nashua or North Chelmsford would need to transfer between local and express trains. During off-peak hours, present schedules would be retained, but the outer terminal for all trains would be Nashua instead of Lowell.

The Alternative 2 service improvements reduce travel times to Boston significantly from stations on the existing Lowell Line—from 33 to 50 percent on express trains, and up to 23 percent on local trains (see Table G-12). In addition, travel times from Nashua and North Chelmsford would be faster than present times from Lowell.

Table G-12
Nashua Extension: Travel Times to North Station (in minutes)

	Existing Service	Future Express	Future Local
Nashua	—	48	—
N. Chelmsford	—	38	—
Lowell	49	33	40
N. Billerica	41	27	35
Wilmington	32	19	26
Mishawum	26	13	20
Winchester	19	—	14
Wedgemere	16	—	12
W. Medford	12	—	8

Ridership Impacts

In the year 2020, faster service, including express trains, would increase weekday ridership at stations on the present Lowell Line by 4,600 (31 percent) under Alternative 1 and by 5,760 (39 percent) under Alternative 2. These increases would include 2,580 to 3,200 new transit trips.

Table G-13
Ridership Impacts of Lowell Line Improvements

	Total Trips	New Transit Trips
Alternative 1		
Existing Line Improvements	4,600	2,560
Alternative 2		
Existing Line Improvements	5,760	3,200
Nashua Extension	1,480	520
Subtotal	7,240	3,720

The number of riders using stations on the Nashua extension—1,480 per weekday—would be less than the number of new riders attracted to present stations by service improvements:

	Mass. Residents	N.H. Residents	Total
Nashua:	25	1,065	1,090
North Chelmsford:	105	285	390
Total	130	1,350	1,480

At these ridership levels, Nashua and North Chelmsford would be the least patronized stations on the Lowell Line north of Route 128. Of the 1,480 trips from these stations, the majority (960) would be made by people that would otherwise board at Lowell or North Billerica, or would use other transit alternatives. Only 520 new transit trips would be made from the extension stations. The diversion of trips to Nashua and North Chelmsford instead of present stations would reduce congestion on Route 3 and would improve air quality in proportion to the shortening of auto access trips.

The Alternative 1 improvements to the existing Lowell Line would attract 63 percent as many new Lowell Line trips and 69 percent as many new transit trips as Alternative 2. Much of the difference between ridership for Alternatives 1 and 2 would consist of increases of 1,160 total trips and 620 new transit trips at Lowell, North Billerica, and Wilmington. These additional trips would be attracted by the doubling of service from 30- minute to 15-minute headways at these stations as the result of originating local trains at Lowell instead of Mishawum. This could also be done without extending service beyond Lowell.

Costs and Cost-Effectiveness

The right-of-way on the existing Lowell Line is in good condition and can already support faster service. As a result, the capital costs to run faster service and express trains would include only the cost of the additional rolling stock required. The service configuration assumed in Alternative 1 would require two additional train sets of one locomotive and six cars each (an increase from four to six sets), at a cost of $17.1 million. The Boston to Lowell portion of Alternative 2 service could also be operated with two additional train sets. Operation of express service from Nashua would require two more train sets than the Lowell to Boston portion of the service, at an additional cost of $17.1 million.

The Nashua extension would also require substantial improvements to the tracks between Lowell and Nashua, and the construction of two stations. This would cost approximately $34.5 million. Including rolling stock, the cost of the Nashua extension would be $51.6 million.[7] Two-thirds of the riders that would use stations on a Nashua extension would otherwise drive to Lowell or North Billerica, or use other transit alternatives. Therefore, the cost for each new transit rider attracted to the extension would be high (see Table G-14).

Table G-14
Cost-Effectiveness of Lowell Line Improvements

	Operating Cost (Annual)	Fare Revenue (Annual)	Capital Cost	Capital Cost/ New Trip
Alternative 1				
Existing Line Improvements	$0.2m	$1.4m	$17.1m	$6,660
Alternative 2				
Existing Line Improvements	$1.8m	$1.8m	$17.1m	$5,330
Nashua Extension	$2.9m	$0.6m	$51.6m	$99,330
Total for Alternative	$4.7m	$2.3m	$68.7m	$18,480

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[7] This cost differs from the cost in the Nashua study due to differences in capital costs for rolling stock. The Nashua study assumed a cost of $7.1 million (presumably for one train set). This examination assumes a higher level of service that would require two train sets.

Compared with the present schedule Alternative 1 would increase annual operating cost by $156,000, but with year 2020 ridership forecasts, it would increase annual revenue by $1,409,000. This would reduce the annual operating deficit by $1,253,000. The savings would substantially exceed the annualized capital cost for this alternative ($682,000). The unusually high revenue to cost ratio would be the result of two factors. First, service levels on the Lowell Line are already relatively high. With faster running times, the net increase in vehicle service hours required by the assumed local and express service configuration would be relatively small. Second, the travel time improvements would attract a significant number of new riders. In addition, because the required capital improvements would be limited to buying new rolling stock, the capital cost per new rider would be low, at $6,660.

Alternative 2 would essentially retain the local train service now operated from Lowell, but add peak-period express service at stations from Lowell through Mishawum. Because this service configuration could be run either with or without a Nashua extension, the analysis subdivided costs and benefits between the existing line and the extension. With Alternative 2 service, the additional fare revenue at existing stations ($1,759,000) would be slightly less than the increased cost of service between Boston and Lowell. ($1,785,000). Compared with Alternative 1, the portion of Alternative 2 service on the existing Lowell Line would attract 24 percent more new transit riders (3,200 versus 2,580) but would increase operating costs by 11.4 times as much ($1,785,000 versus $156,000 per year).

The operating cost for the portion of Alternative 2 service between Lowell and Nashua would be $2,907,000 per year, but fare revenue from new transit riders would be only $562,000. This would result in a revenue to cost ratio of 19 percent. The capital cost per new rider would be much higher than for the existing line improvements, at $99,330.

Air Quality Impacts

Improvements to the existing line would reduce regional emissions by 0.08 percent (Alternative 1) to 0.10 percent (Alternative 2). These are among the largest air quality benefits for improvements to existing services. The capital cost per kilogram of VOC eliminated per day for existing line improvements would be among the lowest, at $194,500 to $243,100 (see Table G-15).

Table G-15
Air Quality Impacts of Lowell Line Improvements

	% Reduction Regional Emissions	Capital Cost/kg of VOC Elim/weekday
Alternative 1		
Existing Line Improvements	0.08%	$243,100
Alternative 2		
Existing Line Improvements	0.10%	$194,500
Nashua Extension	0.02%	$4,080,000
Total for Alternative	0.12%	$684,700

The air quality benefits of the Nashua extension portion of Alternative 2 would be much lower, resulting in a reduction of regional emissions of only 0.02 percent. The cost would also be significantly higher, at $4.1 million per kilogram of VOC eliminated per weekday.

Conclusions

Service improvements on the existing Lowell Line could attract significant ridership increases. These improvements are among very few projects analyzed in the PMT that would reduce, rather than increase, operating deficits. The Alternative 1 improvements would reduce operating losses by $1,253,000 per year and would attract 2,580 new weekday transit riders in the year 2020. The Alternative 2 improvements include higher service levels between Lowell and Wilmington. Compared to Alternative 1, Alternative 2 would attract 24 percent more new transit riders (3,200) to the existing line. Alternative 2 would increase the annual operating deficit by $26,000 per year compared to present service, however.

Excluding the extension beyond Lowell, Alternatives 1 and 2 would each have capital costs of $17.1 million, because each would need two additional train sets and no changes in fixed facilities. Alternative 2 would attract more new riders, so its capital cost per new transit rider ($5,330) would be lower than that of Alternative 1 ($6,660). Both of these costs are very low compared to most other projects examined for the PMT.

The existing line improvements of Alternatives 1 and 2 would also provide relatively high air quality benefits at low cost. The reduction in regional emissions would be 0.08 to 0.10 percent, which are among the highest attainable from improvements to existing commuter rail services. The capital costs per benefit received (measured in number of kilograms of VOC eliminated per weekday) would be the lowest of all rail improvements examined.

In contrast to improvements to the existing Lowell Line, a Nashua extension would compare unfavorably with most other PMT projects. It would attract relatively few new transit trips (only 520 per weekday). At the same time, it would be relatively expensive to build and operate, with total capital costs of $51.6 million, and an operating deficit increase of $2.4 million per year. The Nashua extension would also provide relatively few air quality benefits (a 0.02 percent emissions reduction) at a high cost ($4.1 million per kilogram of VOC eliminated per weekday).

Fitchburg Line Improvements

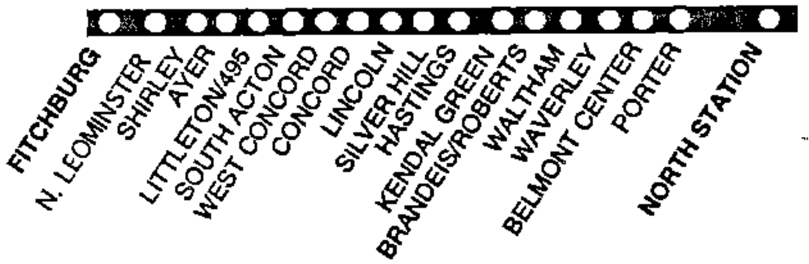
Existing Service

Currently, the Fitchburg Line serves 18 stations (see Figure G-10). Weekday service consists of ten round trips over the full length of the line and six South Acton short turns. (Four of five inbound AM peak trips and three of five PM peak trips cover the full route.) Service operates at 10 to 50 minute headways during peak periods and at headways of up to two hours during off-peak periods.

The number of stations served varies by train. Most trains omit at least one station; only two trips inbound and none outbound have scheduled stops at all stations between Fitchburg and Boston. At the other extreme, one peak-period express train in each direction runs non-stop between Lincoln and Waltham and between Waltham and Porter Square.

The only stations with scheduled stops by all trains that pass through them are Fitchburg, North Leominster, South Acton, Waltham and Porter Square. All trains make at least a flag stop at Concord, and all Fitchburg trains make at least a flag stop at Littleton/495, Ayer, and Shirley. The least-served station on the line is Silver Hill in Weston, where only two inbound and three outbound trains stop all day.

Figure G-10
Fitchburg Line Service



PMT Alternative

For the PMT analysis, a combination of faster maximum operating speeds and peak period express service was examined. This would involve track and right-of-way improvements to increase the maximum operating speed to 70 mph, and the operation of express trains during peak periods. No new branches or extensions of this line were considered.

Express trains would provide service from Concord and beyond, making all stops from Fitchburg to Concord, and then running non-stop to Porter (see Figure G-11). Local trains would operate between Littleton/495 and North Station. In peak periods, local and express trains would both operate at 30-minute headways. Most stations would get at least as much service as they do now. Service would be doubled at South Acton, West Concord, and Concord, which are the highest ridership stations on the line, and at Littleton/495 (see Table G-16). Passengers making interzone trips from stations beyond I-495 to stations east of Concord would transfer at one of the four stations served by both express and local trains.

Figure G-11
Local/Express Service Configuration

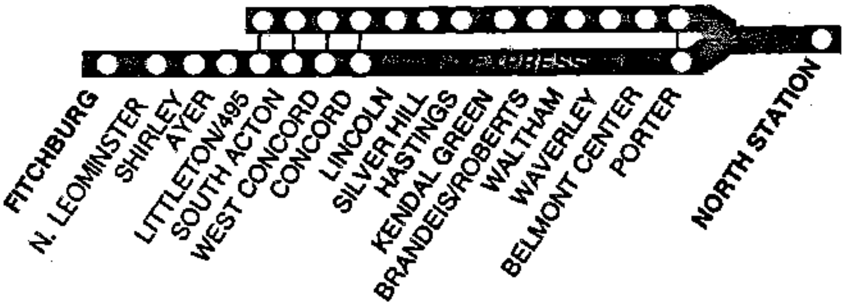


Table G-16
AM Peak Inbound Service Levels
(Number of Trains Serving Each Station)

	Existing			Future		
	Local	Express	Total	Local	Express	Total
Fitchburg	3	1	4	0	5	5
N. Leominster	3	1	4	0	5	5
Shirley	3	1	4	0	5	5
Ayer	3	1	4	0	5	5
Littleton/495	3	1	4	5	5	10
S. Acton	4	1	5	5	5	10
W. Concord	4	1	5	5	5	10
Concord	4	1	5	5	5	10
Lincoln	4	1	5	5	0	5
Hastings	4	0	4	5	0	5
Kendal Green	4	0	4	5	0	5
Brandeis/Roberts	4	0	4	5	0	5
Waltham	4	1	5	5	0	5
Waverley	4	0	4	5	0	5
Belmont	4	0	4	5	0	5
Porter Square	4	1	5	5	5	10

During off-peak periods, present schedules would be retained.

The operation of express trains with 70 mph maximum speeds would reduce travel times significantly—by 14 to 20 minutes compared to current local trains, and by eight to 14 minutes compared to current express trains (see Table G-17). Because of close station spacings and right-of-way constraints, local trains would rarely be able to exceed 60 mph. Therefore, travel time savings at stations served only by such trains would be insignificant.

Table G-17
Faster Fitchburg Line Service: Travel Times to North Station (in minutes)

	Existing Local	Existing Express	Future Local	Future Express
Fitchburg	91	85	—	74
N. Leominster	84	78	—	65
Shirley	77	71	—	58
Ayer	72	66	—	52
Littleton/495	61	55	60	45
S. Acton	50	44	51	36
W. Concord	45	39	45	30
Concord	41	35	41	26
Lincoln	35	28	35	—
Hastings	30	—	29	—
Kendal Green	28	—	27	—
Brandeis/Roberts	25	—	23	—
Waltham	22	19	19	—
Waverley	17	—	15	—
Belmont	15	—	12	—
Porter Square	10	10	7	7

Ridership Impacts

Faster service, including the operation of express trains, would increase Fitchburg Line ridership by 1,138 trips per weekday in the year 2020. Most of these trips (956) would be diverted from automobiles. For the assumed level of service improvements, however, the ridership gain would be relatively small. This is because there are fewer Boston work trips from communities along the Fitchburg Line than from most other MBTA commuter rail corridors. Therefore, even with a high market share, the Fitchburg Line has limited ridership potential.

Costs and Cost-Effectiveness

To operate faster service with express trains on the Fitchburg Line, upgrading of track, signals and switches at selected locations throughout the route would be needed. (The overall maximum speed limit on the line is currently 60 mph, but in the past it was 70 mph.) The capital cost of the necessary improvements would be $21.8 million. In addition, six new train sets would be needed to operate the additional service, at a cost of $51.2 million. The total cost of right-of-way improvements and rolling stock would be $72.9 million. This would result in a capital cost per new transit trip of $76,262. This is the second-highest cost per new trip of any of the alternatives examined for improvements to service on existing commuter rail lines.

The new service level would increase operating costs by $4.2 million per year, but would generate only $0.6 million per year in new fare revenue. This would be a revenue to cost ratio of only 13 percent (see Table G-18).

Table G-18
Cost-Effectiveness of Fitchburg Line Improvements

	Operating Cost (Annual)	Fare Revenue (Annual)	Capital Cost	Capital Cost/ New Trip
Existing Line Improvements	$4.2m	$0.6m	$72.9m	$76,262

Air Quality Impacts

The Fitchburg Line, at 49.6 miles, is the MBTA's longest route. This results in above-average trip lengths, and relatively high VMT reductions for riders diverted from automobiles. Therefore, Fitchburg Line service improvements would have greater air quality benefits than other projects with similar ridership gains. Regional emissions would be reduced by 0.03 percent. Because of the high capital cost of this project, the cost per kilogram of weekday VOC eliminated would be higher than for most commuter rail express services examined, at $2.8 million (see Table G-19).

Table G-19
Air Quality Impacts of Fitchburg Line Improvements

	% Reduction Regional Emissions	Capital Cost/kg of VOC Elim/weekday
Existing Line Improvements	0.03%	$2,789,740

Conclusions

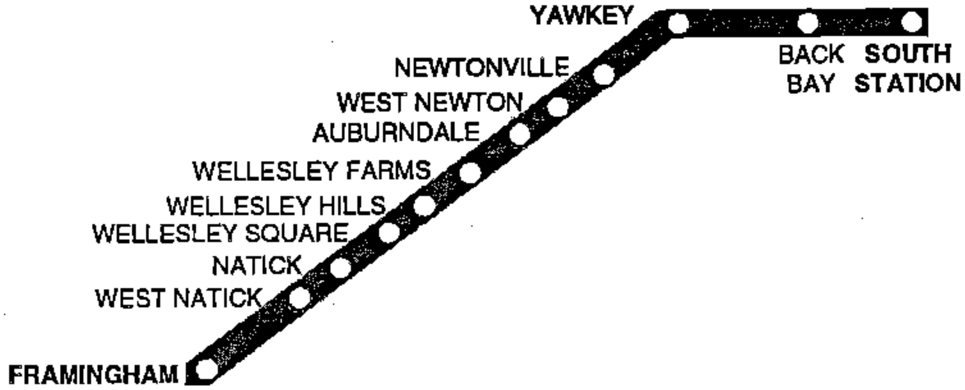
The institution of faster service and the operation of more express trains on the Fitchburg would require a large capital expenditure ($72.9 million). The service improvements would attract a relatively small number of new trips (956), would have a below-average revenue to cost ratio (14 percent) and have only marginal air quality benefits.

Framingham Line Improvements

Existing Service

Currently, the Framingham Line serves 12 stations (see Figure G-12). (Trains only stop at Yawkey Station, near Fenway Park, shortly before and after Red Sox home games.) During peak periods, peak-direction trains stop at all stations (except Yawkey) at headways of 30 to 35 minutes. Most AM peak outbound trains skip some or all intermediate stops.[8] During the mid-day, service operates at headways of one hour and 45 minutes to two hours, and all trains stop at all stations. During the evenings, headways are up to two hours. All outbound evening trains stop at all stations, but only the last two inbound evening trains do so.

Figure G-12
Framingham Line Service



PMT Alternatives

For the PMT analysis, three service expansion alternatives were examined:

1. A combination of faster running times, increased service levels, and express service on the existing line.
2. An extension to Worcester, combined with faster running times, increased service levels and express service.
3. An extension to Marlborough, combined with faster running times, increased service levels, and express service on the existing line to Framingham.

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[8] The first two outbound trips, at 5:00 and 5:20 AM, are essentially equipment-shifting moves, required because there is no layover facility at Framingham. To avoid conflicts with inbound schedules, the next three outbound trains have to use a track that has no access to platforms at some stations.

1. Faster Running Times, Increased Service Levels, and Express Service

The first alternative involves service improvements to the existing line. These include track and right-of-way improvements to increase the maximum operating speed to 70 mph, the operation of increased levels of service, and peak period express trains.

During peak periods, express trains would stop at the Framingham, West Natick, Natick, Wellesley Square, Wellesley Hills, and Wellesley Farms stations, and then run non-stop to Back Bay (see Figure G-13). Local trains would make all stops between Wellesley Farms and South Station. Express and local trains would both operate at 30 minute headways. This would result in 30 minute headways at all outer stations, except Wellesley Farms, where headways would be 15 minutes. Train frequencies would be similar to the present ones at all stations except Wellesley Farms, where service would double. During off-peak periods, present schedules would be retained.

Figure G-13
Express/Local Service Configuration

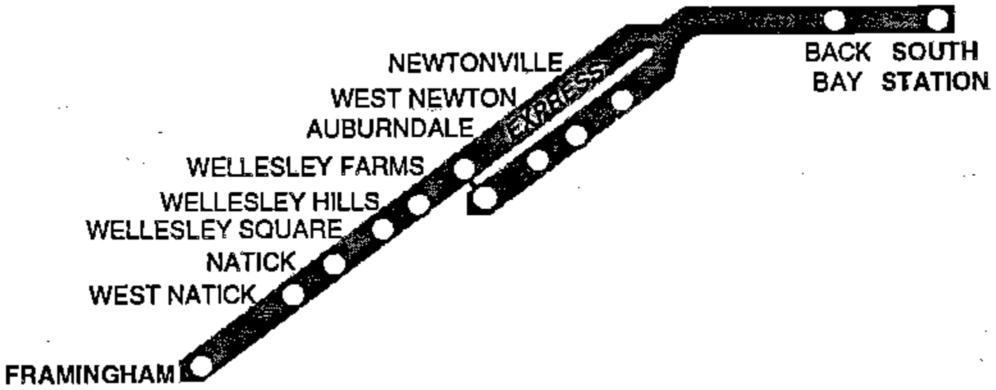

Table G-20
Faster Framingham Line Service: Travel Times to South Station (in minutes)

	Existing Service	Future Local	Future Express
Framingham	50	—	40
West Natick	46	—	37
Natick	41	—	32
Wellesley Square	36	—	27
Wellesley Hills	32	—	23
Wellesley Farms	28	23	21
Auburndale	24	19	—
West Newton	21	16	—
Newtonville	17	13	—
Back Bay	5	4	4

Compared to present service, express trains with higher maximum speeds would reduce travel times by seven to 10 minutes, or by 20 to 25 percent, at outer stations. Time savings on local trains would be smaller, at four to five minutes, or 18 to 24 percent.

2. Worcester Extension

This project would consist of a 23 mile extension of the Framingham commuter rail line (doubling its length) from the present terminal in Framingham through Ashland, Southborough, Westborough, Grafton, and Millbury to Worcester. Preliminary feasibility studies have been completed, and design and engineering work is underway.

There would be six stations on the extension:

Station	Parking	Fare Zone
Ashland	400	7
Southborough	400	7
Westborough	400	7
Grafton	400	8
Millbury	400	9
Worcester	500	10

Table G-21
Worcester Extension: Travel Times to South Station (in minutes)

	Existing Service	Future Local	Future Express
Worcester[9]	—	80	67
Millbury	—	73	60
Grafton	—	69	56
Westborough	—	59	46
Southborough	—	52	39
Ashland	—	47	34
Framingham	50	44	31
West Natick	46	41	—
Natick	41	36	—
Wellesley Square	36	31	—
Wellesley Hills	32	27	—
Wellesley Farms	28	23	—
Auburndale	24	19	—
West Newton	21	16	—
Newtonville	17	13	—
Back Bay	5	4	4

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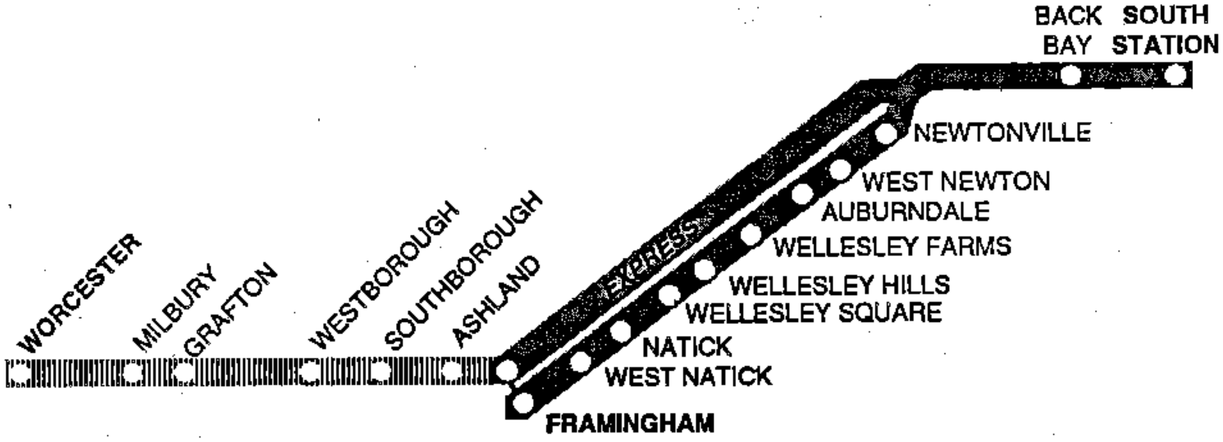
[9] Times from Worcester are two minutes greater than those included in the Feasibility Study due to the addition of Millbury Station.

The alignment for a Framingham-Worcester extension would be the Conrail Main Line. This is the primary route for railroad freight to and from Boston and points in southeastern Massachusetts. It also carries some Amtrak intercity passenger trains.

During peak periods, a combination of express and local trains would be run. In the AM peak, present local service from Framingham to Boston would be retained, but one train would originate at Worcester instead of Framingham. Four new inbound trains would originate at Worcester, make all stops to Framingham, and then run non-stop to Back Bay Station. In the PM peak, all present outbound Framingham local trains would be extended to Worcester. Four new trains would run non-stop from Back Bay to Framingham and then make all stops to Worcester. During off-peak hours, present schedules would be retained, but the outer terminal for all trains would be changed from Framingham to Worcester.

Figure G-14
Service Configuration with Worcester Extension



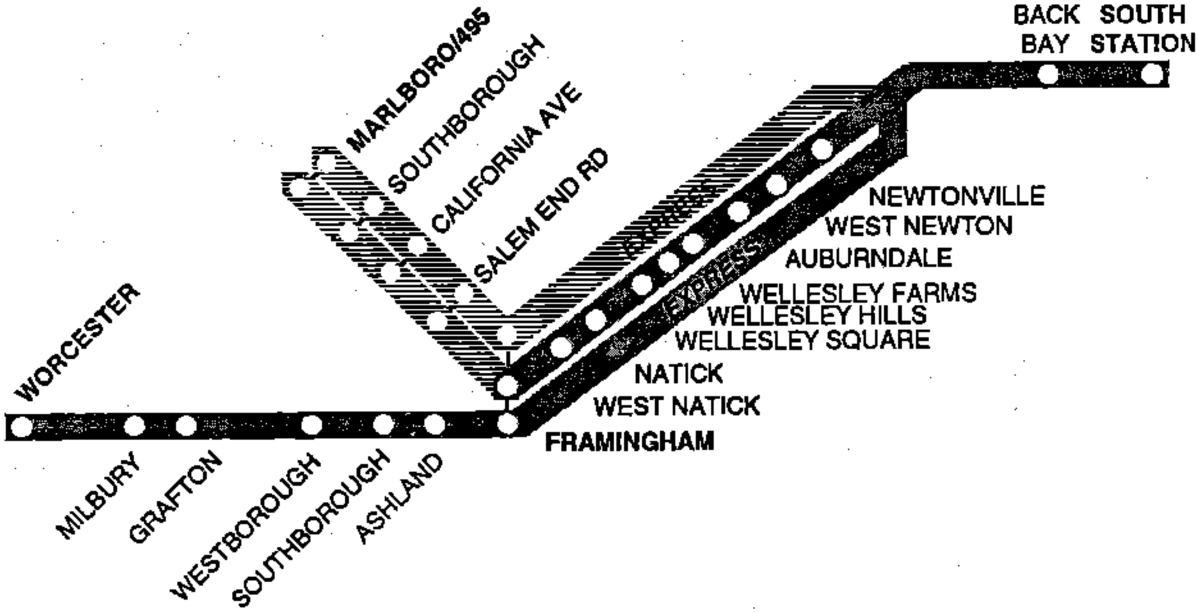
3. Extension to Marlborough with Faster Running Times and Express Trains

Alternative 3 involves a 9.5-mile extension of the Framingham commuter rail line to Route I-495 near the Southborough-Marlborough border (see Figure G-15). This extension, originally proposed as an alternative to the Worcester extension, was examined in the PMT as being run along with the Worcester extension. For purposes of analysis, the service in Alternative 2 was used as the base case against which Alternative 3 was compared. The Marlborough extension would use the Conrail Fitchburg Secondary Track, currently used only for freight service.

There would be four stations on the extension:

Station	Parking	Fare Zone
Salem End Road in Framingham	750 spaces	5
California Ave in Framingham	500 spaces	6
Southborough Center	250 spaces	6
Marlborough at I-495	1,000 spaces	7

Figure G-15
Service Configuration with Marlborough Extension



All service on this extension would operate to and from Marlborough. During peak periods, a combination of express and local trains would be operated. All trains would stop at all stations on the extension and at Framingham. Express trains would then run non-stop to Back Bay, but locals would serve all stops east of Framingham. Express and local trains would both be operated at 60-minute headways. This would provide overall average 30-minute headways at stations on the extension.

With a Marlborough extension, there would be a reduction in peak-period service to and from Worcester. At Framingham station, overall AM peak inbound and PM peak outbound service would include a train every 15 minutes. Half-hourly express trains would alternate with half-hourly locals. Each of these would, in turn, alternate between Worcester and Marlborough trains. There would be no Framingham short-turns. Service to stations between Framingham and Boston would be the same as in the base case, but would be provided by local trains running alternately from Worcester and Marlborough.[10]

During off-peak periods, only local service would be operated on the Marlborough extension. Worcester service would be the same as in the base case, but an equal number of Marlborough trains would be added. This would double service at stations from Framingham to Boston.

Travel times from existing stations to South Station would be the same under Alternatives 2 and 3, as shown in as shown in Tables G-21 and G-22. Compared to present service, travel times to Boston from most stations on local trains would be reduced by four to six minutes.

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[10] Because of differences in running times for express and local trains it would be impossible to establish a schedule with uniform headways at all stations served by both even if equal numbers of trains started from all terminals. (For example, an express train leaving Framingham 15 minutes after a local would arrive at South Station only two minutes later.)

These savings would result from faster speed limits that could be implemented with or without any extensions beyond Framingham. The travel time from Framingham to South Station on express trains would be 31 minutes, or a reduction of 19 minutes compared to the present 50 minute schedule for local trains. Framingham express trains could also be operated with no further extensions, but Framingham alone has insufficient demand potential to justify such service.

Table G-22
Marlborough Extension: Travel Times to South Station (in minutes)

	Existing Service	Future Local	Future Express
Marlborough	—	65	52
Southborough	—	59	46
California Ave	—	55	42
Salem End Road	—	48	35
Framingham	50	44	31
West Natick	46	41	—
Natick	41	36	—
Wellesley Square	36	31	—
Wellesley Hills	32	27	—
Wellesley Farms	28	23	—
Auburndale	24	19	—
West Newton	21	16	—
Newtonville	17	13	—
Back Bay	5	4	4

Ridership Impacts

Under Alternative 1, faster service, including the operation of express trains, would increase ridership on the existing Framingham Line by 1,460 trips per weekday. Of these, 580 (39 percent) would be new transit trips (see Table G-23). This is the third-lowest number of new transit trips for running time improvements on existing commuter rail lines examined for the PMT. (Similar improvements on the Needham Line would attract only 158 new riders.)

In Alternative 2, the Worcester extension combined with faster service and express trains would attract 6,700 new Framingham Line trips per weekday, including 3,470 diversions from automobiles. Most of these trips would be on the extension: 6,010 of the total trips, and 3,200 of the new transit trips. The remainder would be attracted by the faster service on the existing line, including express service from Framingham. Boardings by station on the extension would be as follows:

Worcester	1,045
Millbury	370
Grafton	335
Westborough	620
Southborough	1,770
Ashland	1,870
Total	6,010

Ridership at most individual stations on the extension would be relatively high, but the highest ridership would be at the two innermost stations. To put these figures in perspective, of 97 outer stations in the existing system, only six now have higher ridership than projected for Southborough and only five have higher ridership than projected for Ashland. Excluding the Fall River and New Bedford extensions, which would effectively be new lines, the Worcester extension would attract the highest number of total trips and diversions from automobiles of all commuter rail extensions examined for the PMT.

Table G-23
Ridership Impacts of Framingham Line Improvements

	Total Trips	New Transit Trips
Alternative 1 (Express Service: No Extensions)		
Existing Line Improvements	1,460	580
Alternative 2 (Worcester Extension)		
Existing Line Improvements	690	270
Worcester Extension Segment	6,010	3,200
Total	6,700	3,470
Alternative 3 (Marlborough Extension)		
Marlborough Extension Segment Only	1,630	775

In Alternative 3, a Marlborough extension constructed along with a Worcester extension would attract relatively low total ridership: 1,630 trips per weekday, of which 775 would be diverted from automobiles. The remainder would be diverted from other transit services, primarily the Worcester extension. The low estimated ridership is the result of the overlapping service areas of the Worcester and Marlborough extensions. Every station on a Marlborough extension would be within four miles of either a new station on the Worcester extension or Framingham Station.[11]

On a station by station basis, ridership at all Marlborough extension stations except Southborough would be low:

Marlborough	460
Southborough	865
Salem End Road	125
California Avenue	180
Total	1,630

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[11] The Worcester Feasibility Study ("Commuter Rail Extension Feasibility Study: Framingham to Worcester, Milford & Marlborough," Stone & Webster Civil & Transportation Services, Inc., January 1990) examined the impacts of a Marlborough extension without a Worcester extension. In this case, Marlborough extension would be approximately 3.5 times higher and only slightly lower than ridership on the Worcester extension.

Costs and Cost-Effectiveness

The existing Framingham Line is in good physical condition and can already accommodate service with higher maximum operating speeds. However, the operation of express trains to and from Wellesley Farms would require the construction of a layover facility, at approximately $1.2 million, to prevent scheduling conflicts between express and local trains. In addition, two new train sets would be required, at a cost of $17.1 million (two locomotives and 12 cars). Therefore, the total capital cost to institute express service would be $18.3 million (see Table G-24). Operating costs would be increased by $1.9 million per year, of which only 16 percent ($0.3 million) would be covered by increased fare revenue.

Table G-24
Costs of Framingham Line Improvements

	Operating Cost (Annual)	Fare Revenue (Annual)	Capital Cost	Capital Cost/ New Trip
Alternative 1 (Express Service; No Extensions)				
Existing Line Improvements	$1.9m	$0.3m	$18.3m	$31,800
Alternative 2 (Worcester Extension)				
Total	$7.2m	$4.7m	$119.0m	$34,300
Alternative 3 (Marlborough Extension)				
Total	$8.6m	$0.8m	$73.6m	$95,100

The route of the Alternative 2 extension from Framingham to Worcester currently carries limited Amtrak intercity passenger service (two round trips to Washington via Springfield and one round trip to Chicago per day). The line is relatively well maintained, but would require further upgrading to permit the running times and express service assumed for the PMT. (The present maximum speed limit is 50 mph, and part of the line has been reduced to single track.) There are no stations between Framingham and Worcester now. The total cost for station, track and right-of-way improvements, and for signaling and communications is estimated at $84.9 million. In addition, four new train sets would be needed at a cost of $34.0 million, bringing the total cost to $119.0 million.[12]

The Worcester extension would improve peak-period service at Framingham Station by adding express trains to Boston and increasing the number of departures. Service at stations between Framingham and Boston would not change except for minor schedule adjustments. Therefore, all ridership increases at existing stations would occur at Framingham. Any allocation of the cost of Worcester express service to Framingham Station would necessarily be arbitrary. Demand at Framingham would not support non-stop service to Boston without a Worcester extension. Therefore, benefits and costs of Alternative 2 are not shown separately for the existing line and the extension.

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[12] Earlier estimates put the cost of a Worcester extension at approximately $80 million. The $118.9 million estimates includes higher station costs for high-level platforms and related changes for ADA compliance ($5.9 million) plus vehicle costs ($34.0 million).

Worcester extension service would increase operating costs by $7.2 million per year, and would generate approximately 65 percent of these costs in fare revenue ($4.7 million). This is the second-highest revenue to cost ratio for any commuter rail extension examined for the PMT, below only that for Newburyport service (75 percent). The capital cost per new rider would be $34,300, which would be the second lowest cost among the extensions examined to date (again after Newburyport).

The Marlborough extension would operate on the Conrail Fitchburg Secondary line, which is currently used only for freight service. This line would require considerable rehabilitation and installation of a signal system. The total cost for station, track and right-of-way improvements, and for signaling and communications is estimated at $48.0 million. The schedule assumed in the analysis of Alternative 3 would require three more train sets than needed for Alternative 2. With one locomotive and six coaches per train, these would cost $25.6 million.[13] Including the cost of the six new train sets, the total cost would be $73.6 million.

Ridership estimates were developed only for the extension segment of Marlborough service, and thus estimates of operating revenues are available for that segment only. As with the case of the Worcester extension, the existing Framingham Line would receive more service as the result of the Marlborough extension, but any allocation of Marlborough service costs to the present line would have to be arbitrary. In any case, the Marlborough extension would show low cost-effectiveness. The net difference in annual operating costs between the Worcester service of Alternative 2 and the combined Marlborough and Worcester service of Alternative 3 would be $8.6 million per year. The additional revenue generated from new transit riders would be only $0.8 million per year, or 9.5 percent of operating costs. The capital cost per new transit rider ($95,100) would place the Marlborough line among the more costly commuter rail extensions examined.

Air Quality Impacts

Alternative 1 improvements to the existing Framingham Line alone would reduce regional emissions by 0.02 percent (see Table G-25). This is the second lowest air quality benefit for improvements to an existing service. (Only Needham Line improvements would have lower benefits.) The capital cost per kilogram of VOC eliminated per day would be in the middle range of improvements to existing lines, at $1.1 million.

The Worcester extension would reduce regional emissions by 0.10 percent. This figure is relatively high; with one exception, the only PMT projects with comparable air quality benefits are significantly more expensive. (The one exception is the provision of better bus circulation within downtown Boston. Projects with greater air quality benefits but higher costs include the North Station–South Station Rail Link, a circumferential rail line, and Blue Line extensions that include the Red-Blue Connector.) The capital cost per kilogram of VOC eliminated by weekday by Worcester service would be $1.5 million. This is a moderate cost for a rail extension.

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[13] For purposes of analysis, this project was originally defined so that the same service frequencies would be provided on the Worcester and Marlborough extensions. The resulting ridership projections indicate that less frequent service on the Marlborough line would be appropriate. This could reduce vehicle requirements and associated capital costs as well as operating costs.

Marlborough service would reduce regional emissions by 0.04 percent. The capital cost per kilogram of VOC eliminated per weekday would be $2.3 million, making this one of the most costly PMT commuter rail alternatives in this measure.

Table G-25
Air Quality Impacts of Framingham Line Improvements

	% Reduction Regional Emissions	Capital Cost/kg of VOC Elm/Weekday
Existing Line Improvements	0.02%	$1,126,100
Worcester Extension	0.10%	$1,452,400
Marlborough Extension (Extension Segment Only)	0.04%	$2,334,000

Conclusions

The operation of Alternative 1 express service on the existing Framingham Line would attract only 580 new transit trips per weekday. The cost per new rider ($31,800) would be significantly higher than those of service improvements on the Rockport/Ipswich, Haverhill/Reading and Lowell Lines, but lower than the comparable costs for all other existing lines. Because the number of diversions from automobiles would be small, the air quality benefits would be low, with a 0.02 percent reduction in regional emissions. The cost per kilogram of weekday VOC eliminated ($1.1 million) would be in the mid-range of such costs for improvements to existing commuter rail lines. It would, however, be low to moderate compared with costs for new services.

A Worcester extension would serve a total of 6,700 trips per weekday, of which 3,470, or 52 percent would be new transit trips. This is the highest number of new transit trips that would be attracted by any commuter rail extension examined in the PMT, and is higher than the number of new trips that would be attracted by most other kinds of new services as well. (Some exceptions are the North Station–South Station Rail Link, the Red Line–Blue Line Connector, and a rapid transit extension to Medford Hillside.) The $119 million capital cost of the extension would average $34,300 for each new transit rider attracted. This is lower than the comparable cost for any commuter rail extension examined except Newburyport or for any Red, Blue, or Orange Line extension.

A Worcester extension would also reduce regional emissions by 0.10 percent, which is high relative to most individual projects. The only rail projects—commuter rail, rapid transit, or light rail—with greater air quality benefits would be significantly more expensive. The capital cost per unit of air quality benefit (kg of VOC eliminated per weekday) would be in the middle range for commuter rail extension projects. The Worcester extension would also recover 65 percent of its $7.2 million annual operating costs from fares. This is the second-highest revenue to cost ratio of any commuter rail extension examined, and is much higher than that of the existing commuter rail system as a whole.

Most of the service area of a Marlborough extension would overlap that of a Worcester extension. Therefore, the increase in ridership as a result of operating both extensions instead of a Worcester extension alone would be relatively small—only 775 new transit riders per weekday. A Marlborough extension would be among the most expensive PMT projects measured in capital cost per new transit rider and per unit of air quality improvement. It would also be expensive to operate and would generate only 9.5 percent of its operating costs in new fare revenue.

Needham Line Improvements

Existing Service

Currently, the Needham Line runs from South Station to Needham Heights and serves 12 stations (Needham Heights, Needham Center, Needham Junction, Hersey, West Roxbury, Highland, Bellevue, Roslindale Village, Forest Hills, Ruggles, Back Bay and South Station). The outer four stations are in the town of Needham; all others are within the City of Boston. At 13.6 miles, this is the second-shortest MBTA commuter rail line, and it has more closely spaced stations than other lines. Needham trains, along with most Franklin Line and Attleboro/Stoughton Line trains, use Amtrak's Boston-New Haven Main Line between South Station and Forest Hills, (5.2 miles), where the Needham Branch diverges. (Only Needham trains serve the Forest Hills commuter rail platform.) The Orange Line shares the right of way of the Main Line between Back Bay Station and Forest Hills.

At present, there are 17 trains in each direction on the Needham Line on weekdays. Eleven round trips cover the full route to Needham Heights. The other six run only from South Station to Needham Junction (12.0 miles). In AM peak hours, three of six inbound trains start at Needham Heights, at intervals of 42 and 48 minutes. Combined headways at Needham Junction range from 19 to 48 minutes. All five outbound PM peak trains run through to Needham Heights, at intervals of 30 to 40 minutes. Mid-day headways range from one to two hours, with no service to Needham Heights or Needham Center between 9:30 a.m. and 4:30 p.m. Evening headways range from 60 to 75 minutes, with all service running through to Needham Heights.

All peak- period peak-direction trains stop at all stations between South Station and Needham Junction or Needham Heights. Some off-peak and off-peak-direction trips skip one or more stations, mostly because of schedule constraints imposed by track layout.

PMT Alternatives

For the PMT analysis, two service improvement alternatives were examined:

1. A combination of faster running times and express service on the existing line.
2. An extension to Millis, combined with faster running times and express service on the existing line.

1. Express Service with Higher Maximum Speeds

The first alternative involves service improvements to the existing line. These include the operation of express trains during peak periods, an increase in the maximum operating speed to 60 mph,[14] and the doubling of service from Hersey Station.

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[14] The maximum operating speed for the Needham Line, at 60 mph, is lower than the 70 mph maximum speed tested on other lines. The lower maximum speed is the result of close station spacing on the Needham Line, which would not allow trains to reach speeds higher than 60 mph.

Peak-period express trains would serve all stations outside Route 128, (the four Needham stations), and then run non-stop to Ruggles (see Figure G-16). Hersey Station would be the outer terminal for peak-period local trains. These would provide all service at stations from West Roxbury to Forest Hills. Peak-period local and express trains would both run on 30-minute headways. Compared to the assumed base case, peak frequencies would not change except at Hersey, where service would be doubled. During off-peak periods, all service would be provided by local trains serving all stations.

Under this alternative, peak travel times would be reduced significantly at stations served by express trains—from 14 to 15 minutes, or by 34 to 42 percent (see Table G-26). Because of close station spacings, travel time reductions on local trains would range only from one to four minutes at each station.

Figure G-16
Express/Local Service Configuration

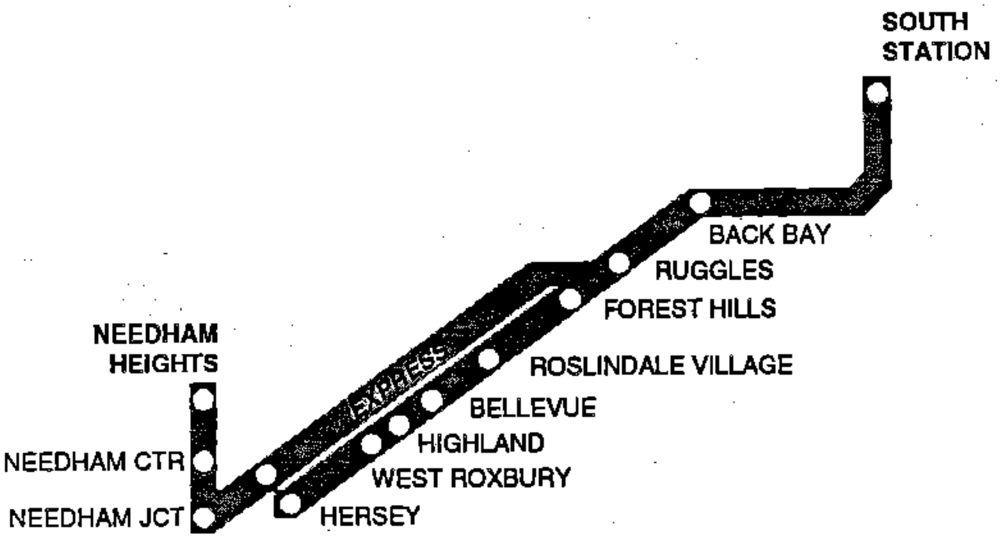


Table G-26
Faster Needham Line Service: Travel Times to South Station (in minutes)

	Existing Service	Future Express	Future Local
Needham Heights	44	29	—
Needham Center	40	24	—
Needham Junction	36	20	—
Hersey	33	17	30
W. Roxbury	28	—	24
Highland	25	—	21
Bellevue	21	—	19
Roslindale Village	17	—	16
Forest Hills	14	—	13
Ruggles	9	9	9
Back Bay	5	5	5

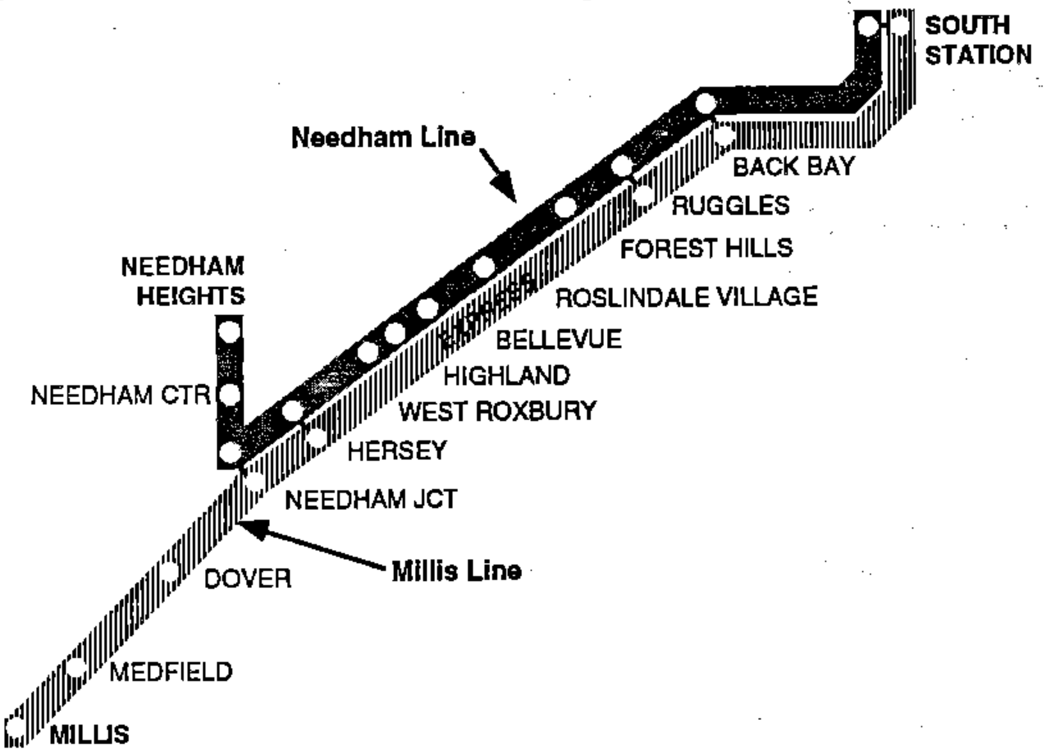
2. Service to Millis

The second alternative for the Needham Line consists of restoring service to Millis via Dover and Medfield. This service would effectively be a new line, sharing the same right-of-way as the Needham Line between South Station and Needham Junction. It would then continue 6.9 miles via the Dover Secondary Track to Medfield Junction and 2.2 miles via the Clicquot Secondary Track to Millis. (These are both parts of the former New York & New England Railroad Woonsocket Division Main Line, which once continued beyond Millis to Woonsocket, RI.) The Needham Junction-Millis right of way is now owned by the MBTA, and is used for freight service operated by the Bay Colony Railroad under a contract with EOTC. Passenger train service from Needham Junction to Millis was last operated in 1967.

There would be three stations on the extension:

Station	Parking	Fare Zone
Dover Center, at Springdale Avenue	200 spaces	3
Medfield Junction, at Adams Street	400 spaces	4
Millis, near Union Street	400 spaces	5

Figure G-17
Millis Extension: Peak Period Service Configuration



As examined in the PMT, Millis service would operate as a new line, and would not change the operation of Needham Line service. During peak periods, the only stations that would be served by both lines would be Needham Junction, Hersey, Ruggles, Back Bay and South Station. Needham Line trains would continue to stop at all stations they now serve. Millis trains would make no stops between Hersey and Ruggles (see Figure G-17).

Peak-period Needham and Millis trains would both operate at 30-minute headways. This would provide 30-minute headways at all stations west of Ruggles except Needham Junction and Hersey, which would have 15-minute headways. Current Needham Line passengers would be able to use Millis Line express trains at the latter two stations (see Table G-27). For these passengers, travel times would be reduced by 16 minutes. For other Needham Line passengers, slightly faster service attributable to 60 mph maximum speeds would reduce travel times by one to four minutes.

Off-peak service would be operated with local trains alternating from Millis and from Needham Junction or Needham Heights. This would provide approximately hourly headways at all stations from Needham Junction to South Station.

Table G-27
Millis Service: Travel Times to South Station (in minutes)

	Existing Service	Peak Period Express	Off-Peak Local
Millis	—	35	48
Medfield	—	31	44
Dover	—	25	38
Needham Junction	36	20	33
Hersey	33	17	30
W. Roxbury	28	—	24
Highland	25	—	21
Bellevue	21	—	19
Roslindale Village	17	—	16
Forest Hills	14	—	13
Ruggles	9	9	9
Back Bay	5	5	5

Ridership Impacts

Under Alternative 1, the operation of express trains would increase Needham Line ridership by 555 trips per weekday, including 160 new transit trips (see Table G-28). The majority of the riders would be diverted from other commuter rail lines or from local buses feeding the Orange Line. This is the second smallest number of total trips and smallest number of new transit riders projected for improvements on any existing commuter rail line.

Table G-28
Ridership Impacts of Needham Line Improvements

	Total Trips	New Transit Trips
Needham Line Express Service	555	160
Millis Service	1,820	855

The Millis extension would attract a higher number of total trips—1,820 per weekday—and new transit trips—855—than the existing line improvements. A Millis extension would serve more total trips than any other commuter rail extension examined except those to Worcester and New Bedford/Fall River. In diversions from automobile use to transit, a Millis extension would rank fourth, after Worcester, New Bedford/Fall River, and Newburyport. By station, ridership would be:

Millis	760
Medfield	740
Dover	320
Total	1,820

At these ridership levels, the Millis and Medfield stations would have higher ridership than most of the Needham Line stations now do. They would also serve more riders than the majority of individual stations on other lines now serve.

Costs and Cost-Effectiveness

The Needham line was reconstructed in 1987 as part of the Southwest Corridor project (and the ties have since been replaced because the originals were defective), and is in good condition. The line beyond Forest Hills is single track with three passing tracks (one near Forest Hills, one in West Roxbury, and one at Needham Junction). Depending on train schedules, improved service could require more passing sidings or a double track. For purposes of analysis it was assumed that PMT Alternative 1 would require no new track, and that the only capital costs would be those of two additional train sets. With six-car trains, this cost would be $23.3 million. The capital cost per new weekday transit trip attracted ($147,300) would be the highest for all the commuter rail express alternatives examined, and nearly double that of the second-highest (the Fitchburg Line).

The combination of local and express trains on the Needham Line in Alternative 1 would increase operating costs by $1.5 million per year compared with local service only, but would increase fare revenue by only $50,000. This would be a farebox recovery rate of less than four percent for the new service.

The restoration of passenger service to Millis would require the upgrading and signalization of 9.1 miles of track between Needham Junction and Millis. This is a single-track line. Because of several cut and fill sections, it could be difficult to double track it. The level of service assumed for PMT Alternative 2 could be operated with a single track, and the capital costs are for single track upgrading. Between Needham Junction and Forest Hills, Millis

Table G-29
Cost-Effectiveness of Needham Line Improvements

	Operating Cost (Annual)	Fare Revenue (Annual)	Capital Cost	Capital Cost/ New Trip
Needham Line Express Service	$1.5m	$0.05m	$23.3m	$147,300
Millis Service	$5.6m	$1.2m	$66.7m	$78,000

trains would run on the present Needham Line. This single-track section would need to be double-tracked to accommodate the additional service. (Right of way width is not a problem here, as this was once a double-track line.) Three new stations and a layover facility would need to be constructed on the extension. The total cost for the stations and right-of-way improvements would be $41.2 million. To run Millis service, three new train sets would be needed at a total cost of $25.6 million. This would bring the total capital cost of the new service to $66.7 million. The capital cost per new weekday transit trip would be $78,000. The latter cost, while relatively high, is lower than those of all other commuter rail extensions examined for the PMT except the Worcester and Newburyport extensions.

Millis service would increase annual operating costs by $5.6 million, and would recover 21 percent of this ($1.2 million) in fare revenue. It would be one of the more expensive commuter rail extensions to operate, because it would require running new trains all the way to or from Boston on every trip rather than extending trains beyond an existing suburban terminal. (It would be similar in this respect to the Fall River/New Bedford extension, and the express component of Worcester service.) Operation of Millis trains as extensions of Needham trains would require discontinuance or reduction of service to Needham Center and Needham Heights, because the route to Millis diverges at Needham Junction. The option of discontinuing service to Needham Center and Needham Heights was tested early in the PMT process, but was dropped from further consideration because it would cause large losses in Needham ridership. An intermediate strategy involving replacement of some Needham Heights service with Millis service has not yet been tested, but could prove to be more cost-effective than the operation assumed for Alternative 2.

Air Quality Impacts

The operation of express service on the Needham Line would reduce regional emissions by less than 0.01 percent. This small reduction is because of the low number of automobile trips that would be diverted, and the short average lengths of these trips (especially compared with diversions to other commuter rail lines). The capital cost per kilogram of VOC eliminated per weekday would be among the highest for all PMT projects.

A Millis extension would reduce regional emissions by 0.03 percent. The capital cost per kilogram of VOC eliminated per weekday would be $2.4 million. This is among the highest costs of all commuter rail extensions examined.

Table G-30
Air Quality Impacts of Needham Line Improvements

	% Reduction Regional Emissions	Capital Cost/kg of VOC Elim/weekday
Needham Line Express Service	<0.01%	$15,319,000
Millis Service	0.03%	$2,386,000

Conclusions

The operation of express service on the Needham Line would generate very few new trips. As a result, institution of express service would not be a cost-effective way to increase ridership or improve air quality. It should be noted, however, that the demand analysis for an Orange Line extension to Needham showed that more frequent service would generate significant ridership increases at existing stations in West Roxbury and Roslindale, as well as at new stations at VFW Parkway and Route 128 (see "Orange Line Extension to Needham" section). These results indicate that more frequent service would have greater impact than faster travel times in this corridor. Operation of more frequent commuter rail service on the Needham Line with additional stations would be less costly than a rapid transit conversion.

A commuter rail line to Millis would be one of the better extensions examined in total ridership (1,820) and in automobile diversions (855). It would also be among the more costly to operate, at $5.6 million, and would recover only 21 percent of this in fares. In air quality benefits, it would be one of the less effective extensions, reducing regional emissions by 0.04 percent.

PMT Alternatives

For the PMT analysis, three service improvement alternatives were examined:

1. A combination of faster running times, increased service levels, and express service on the existing line.
2. An extension to Milford combined with faster running times, increased service levels and express service.
3. Service to Foxborough, which would be operated as a branch of the Franklin Line, combined with faster running times, increased service levels, and express service on the existing line to Forge Park.

1. Faster Running Times, Increased Service Levels, and Express Service

The first alternative involves service improvements to the existing Franklin Line. These include track and right-of-way improvements to increase the maximum operating speed to 70 mph, the operation of increased levels of service, and peak-period express trains.

During peak periods, express trains would serve the Franklin Line's highest ridership stations beyond Route 128: Norwood Depot, Norwood Central, Walpole, Norfolk, Franklin, and Forge Park/495. Local trains would also operate the entire length of the line and make all stops (see Figure G-19). Express and local trains would both operate at 30 minute headways. This would result in 15 minute headways at stations served by express and local trains, and 30-minute headways at stations served only by local trains. Service frequencies would be similar to present ones at stations served only by local trains, but would approximately double at stations served by both local and express trains. During off-peak hours, existing schedules would be retained.

The operation of express service with a 70 mph maximum speed would reduce travel times by up to 13 minutes, or by 15 to 20 percent from stations outside Route 128 (see Table G-31). Travel times on local service would be unchanged, because the large number of closely spaced stops would prevent trains from reaching higher speeds than they do now.

2. Milford Extension

The second alternative involves a 5.9-mile extension of the Franklin commuter rail line from the present Forge Park/495 terminal to Milford. There would be two new stations on the extension: one in Bellingham and one in Milford. Both stations would be in Zone 7. Each station would have 500 parking spaces. In addition, a layover facility would be located in Bellingham. The extension would be entirely outside the MBTA District.

The extension would use part of the Milford Secondary Track currently used only for freight service. This line is owned and operated by Conrail, but is under lease to the MBTA. Purchase of the line by the MBTA has been under negotiation for several years, but has been delayed by a lack of funding.

Figure G-19
Express/Local Service Configuration w/o Extension

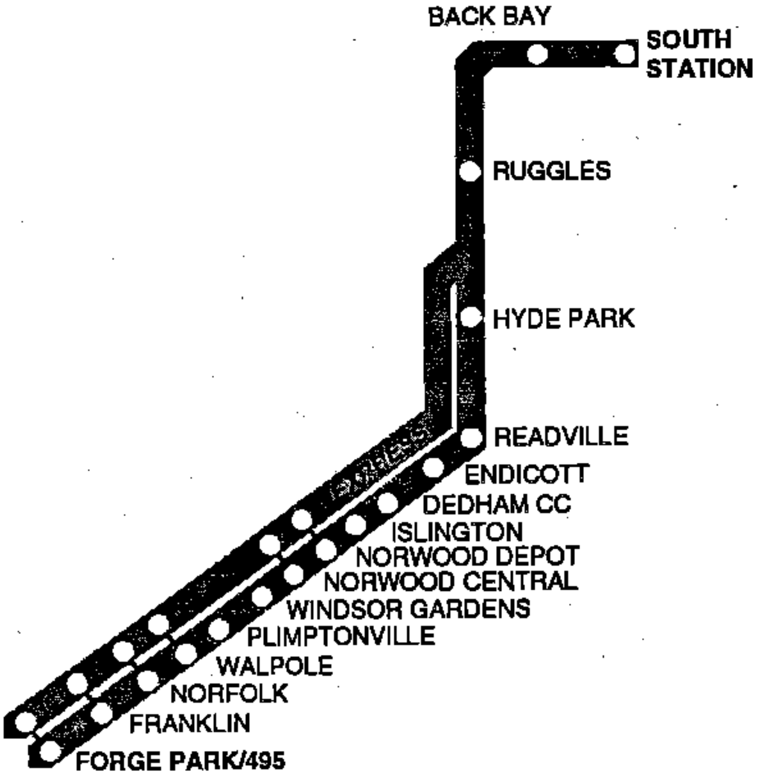


Table G-31
Faster Franklin Line Service: Travel Times to South Station (in minutes)

	Existing Service	Future Local	Future Express
Forge Park/495	66	66	53
Franklin	59	59	46
Norfolk	52	52	39
Walpole	46	46	32
Plimptonville	43	43	—
Windsor Gardens	40	40	29
Norwood Central	36	36	25
Norwood Depot	33	33	22
Islington	30	30	—
Dedham Corporate Center	27	27	—
Endicott	23	23	—
Readville	20	20	—
Ruggles	9	9	9
Back Bay	5	5	4

Figure G-20
Express/Local Service Configuration with Milford Extension

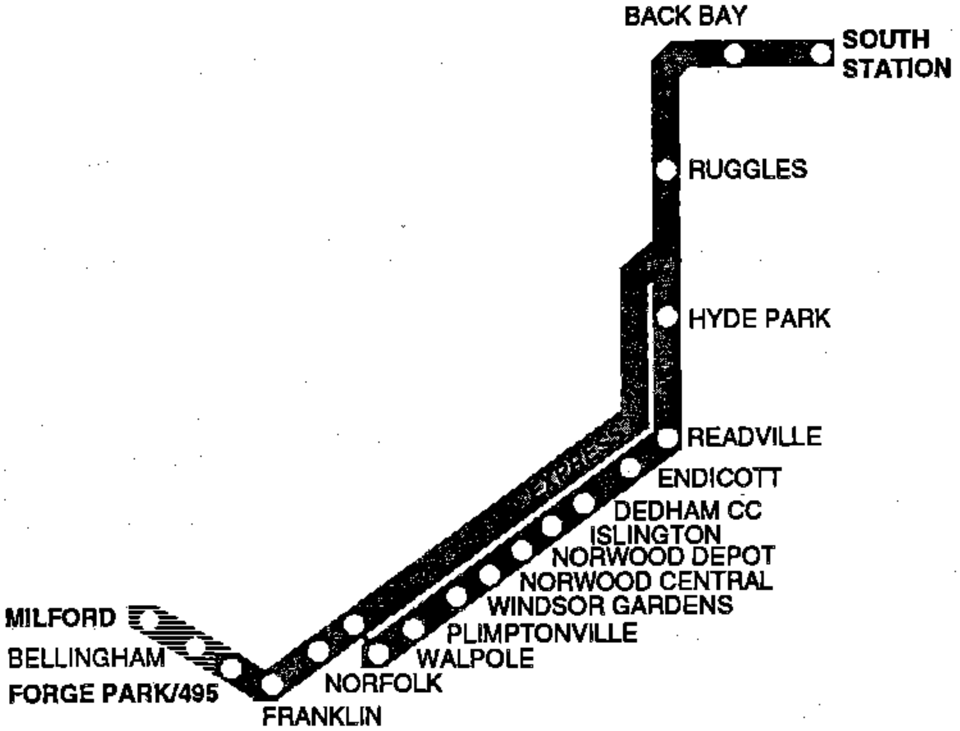


Table G-32
Milford Extension: Travel Times to South Station (in minutes)

	Existing Service	Future Local	Future Express
Milford	—	—	57
Bellingham	—	—	51
Forge Park/495	66	—	46
Franklin	59	—	39
Norfolk	52	—	32
Walpole	46	46	26
Plimptonville	43	43	—
Windsor Gardens	40	40	—
Norwood Central	36	36	—
Norwood Depot	33	33	—
Islington	30	30	—
Dedham Corporate Center	27	27	—
Endicott	23	23	—
Readville	20	20	—
Ruggles	9	9	9
Back Bay	5	5	4

A combination of express and local trains would be run during peak periods, each at 30 minute intervals. Trains originating in Milford would serve Milford, Bellingham, Forge Park/495, Franklin, Norfolk and Walpole before operating non-stop to Ruggles Station (see Figure G-20). Local service would run between Walpole and South Station. During off-peak hours, existing schedules would be retained, but all Forge Park trains would be extended to Milford.

Travel times from existing stations to South Station would be as shown in Table G-32. Travel times on express trains to and from Forge Park/495, Franklin, Norfolk, and Walpole would be 20 minutes faster than they now are. Express travel times from Milford and Bellingham would be faster than current travel time from Forge Park/495. Travel times on local trains would be unchanged.

3. Foxborough Branch

This alternative would add a 3.9-mile branch from the present Franklin Line at Walpole Station to Foxborough. It would use part of a line now owned by Conrail and operated only for freight service.[15] The Foxborough Station would be located near Foxborough Stadium, where existing parking facilities would be used by commuter rail riders. This station would be in Zone 5.

During peak periods, a combination of express and local trains would be run (see Figure G-21). Express trains would serve Forge Park/495, Franklin, Norfolk, and Walpole, and then run non-stop to Ruggles. Local trains would run to and from Foxborough, and make all stops on the Franklin Line from Walpole to South Station. Express and local trains would each run at 30-minute intervals. This would provide 30-minute headways at all stations except Walpole, where average headways would be 15 minutes. The travel time between Foxborough and South Station would be 52 minutes. Travel times on Forge Park/495 express trains and on local trains would be the same as those shown in Table G-32 for a Milford extension.

During off-peak hours, train frequencies to and from Forge Park would remain about the same as under present schedules, but would be supplemented by a similar number of Foxborough trains. This would double off-peak service at stations from Walpole to Boston.

Ridership Impacts

Under Alternative 1, faster service, including the operation of express trains, would increase ridership on the existing Franklin Line by 2,580 trips per weekday. Of these, 1,245, or 48 percent, would be new transit trips (see Table G-33). These increases would be the third largest attainable through the operation of express service on existing lines (after the Lowell and Haverhill/Reading lines).

The Milford extension alternative would attract 2,310 total trips, and 1,015 new transit trips. However, most of these trips would be attracted by the express service from Forge Park/495, Franklin, Norfolk, and Walpole; only 380 total trips, and 85 new transit trips would use Bellingham and Milford stations:

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[15] Past passenger service on this line was not oriented to Boston commuting, and ended in 1933. The line was later used for special trains to events at the race track and stadium in Foxborough.

Milford	340
Bellingham	40
Total	380

The low projected ridership at these stations is the result of the short length of the extension and the location of the current Forge Park terminal at I-495. The Bellingham and Milford stations would also be near I-495, but for most riders using auto access, total travel trip would be shortest using Forge Park Station. Alternative 2 would improve service for fewer

Figure G-21
Service Configuration with Foxborough Branch

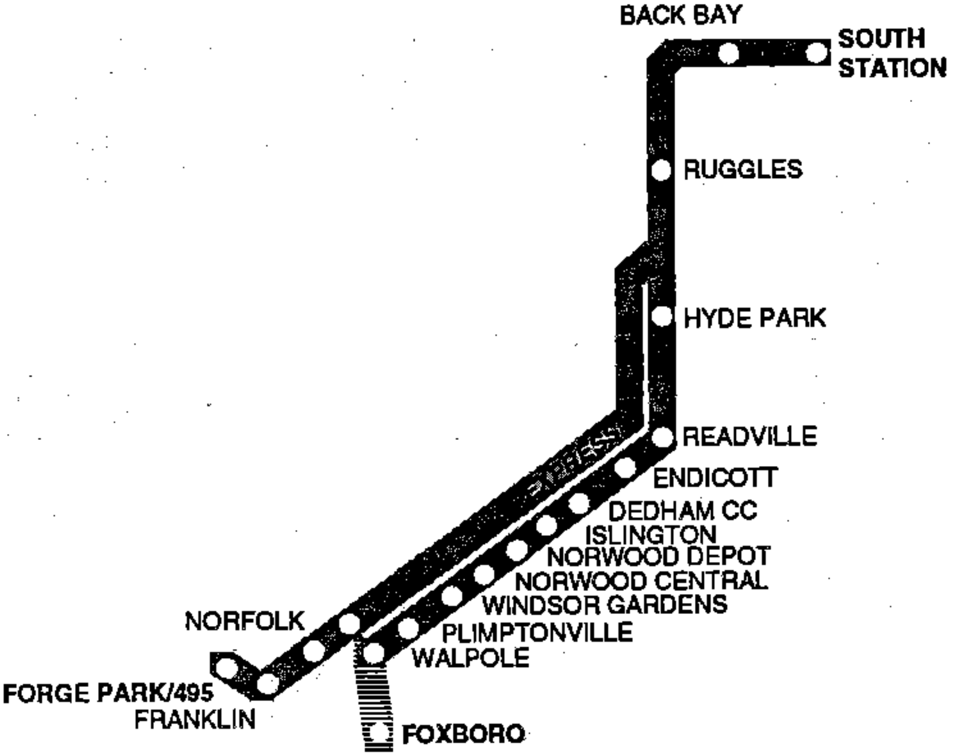

Table G-33
Ridership Impacts of Franklin Line Improvements

	Total Trips	New Transit Trips
Alternative 1 (No Extension)		
Existing Line Improvements	2,580	1,245
Alternative 2 (Milford Extension)		
Existing Line Improvements	1,930	930
Milford Extension Segment	380	85
Total	2,310	1,015
Alternative 3 (Foxboro Service)		
Existing Line Improvements	1,540	810
Foxboro Branch	40	10
Total	1,580	820

users of the existing Franklin Line than Alternative 1, because the innermost stop for Milford express trains would be Walpole instead of Norwood Depot.

Foxborough branch service would attract very low ridership: only 40 total trips and 10 new trips per day on the branch. This poor performance would result from the proximity of Foxborough Station to the Attleboro Line, which would provide much faster service (38 minutes to Boston from Mansfield or 28 minutes from Sharon versus 52 minutes from Foxborough Station).

Costs and Cost-Effectiveness

Franklin Line trains use the same route as Attleboro/Stoughton trains between Boston and Readville, where they diverge onto the Franklin Branch. The branch is double-tracked as far south as Norwood Central; the remainder is single track, with passing tracks at Walpole and Franklin This would cause some scheduling constraints, unless more passing tracks were added. Off-peak direction service would have to be reduced to permit the peak direction frequencies of Alternative 1.

The capital cost estimate for Alternative 1 includes relocation of the Franklin layover facility to Bellingham, for approximately $20 million. In addition, Alternative 1 would increase the number of train sets required to operate the Franklin Branch from six to 10. However, service is now operated with nine-car train sets; with more frequent service, this could be reduced to seven-car sets. Therefore, the total increase in rolling stock required would be four locomotives and 16 cars, at a cost of $25.8 million. The total cost of right-of-way improvements and rolling stock would be $45.8 million (see Table G-34).

Table G-34
Costs of Franklin Line Improvements

	Operating Cost (Annual)	Fare Revenue (Annual)	Capital Cost	Capital Cost/ New Trip
Alternative 1				
Existing Line Improvements	$2.9m	$0.7m	$45.8m	$36,800
Alternative 2 (Milford Extension)				
Existing Line Improvements	-$0.3m	$0.6m	$45.8m	$49,300
Milford Extension	$2.3m	$0.2m	$28.0m	$337,000
Total	$2.0m	$0.8m	$73.8m	$72,800
Alternative 3 (Foxborough Branch)				
Existing Line Improvements	$1.9m	$0.4m	$13.5m	$16,700
Foxborough Branch	$0.9m	$0.0m	$14.1m	$1,763,000
Total	$2.8m	$0.4m	$27.6m	$33,800

The capital cost per new transit rider for Franklin Line express service would be $36,800. This cost is in the mid-range for improvements to existing commuter rail lines, but is much higher than those for the Rockport/Ipswich, Haverhill/Reading and Lowell Lines. Nearly half of the cost is attributable to the relocation of the Franklin layover facility. The current facility has capacity for only three of the six train sets needed to operate the line. The other three sets are kept in Boston at night. They all make their first outbound runs around 4:00

a.m. and seldom carry any passengers. Without a new layover facility, the four additional sets required in Alternative 1 would also have to be based in Boston, but little capacity remains there.

Alternative 1 service would increase operating costs by cost $2.9 million per year compared to present service, and would increase revenue by $0.7 million per year. This would make a revenue-to-cost ratio of only 24 percent. The low ratio is attributable more to a large increase in operating costs than to low ridership. The Franklin Line currently has a slightly lower level of service than most other lines. As a result, the proportional increase in vehicle service hours between present and proposed schedules for the Franklin Line would be higher than average. The PMT results show that the higher level of service would attract a significant number of new riders (the third highest for express service, behind the Haverhill/Reading and Lowell lines), but that a level of service as high as that tested would not be justified. Future investigation of commuter rail express services should examine the ridership and cost impacts of a lower level of express service.

The extension from Forge Park/495 to Milford would cost $18.4 million for track, signals, and new stations at Bellingham and Milford.[16] One additional train set (one locomotive and seven cars) would be required to operate service along the extension. At $9.6 million, this would raise the total cost to $28.0 million. The capital cost per new rider would be $337,000. This would be among the highest such costs for all projects examined.

The Milford extension would increase operating costs by a total of $2.3 million per year, and would generate only seven percent of these costs in fare revenue ($0.2 million). This would be the second worst farebox ratio of any of the extensions examined (better than only the Foxborough extension). (With the schedule assumed for Milford service. operating costs for the existing line would be reduced by $0.3 million per year and revenues increased by $0.6 million per year compared to existing service. These benefits are not allocated to the Milford extension, as they would not depend on operation of any service beyond Forge Park.)

The Foxborough branch would cost $11.4 million for track upgrading, signals, a new station, and a layover facility. Three new train sets would be needed to operate local service from Foxborough and express service from Forge Park/495. Assuming the operation of seven-car trains, three new locomotives and nine cars would be needed at a cost of $16.3 million. Of these rolling stock costs, approximately $2.7 million would be attributable to the new service on the Foxborough branch, and the remainder to improved service on the existing line. The total capital cost of the right-of-way improvements and rolling stock costs attributable to Foxborough service would be $14.1 million. The capital cost per new rider would be $1,763,000. This cost is, by far, the highest for any PMT project.

Foxborough branch service would cost approximately $0.9 million per year to operate and generate only $8,000 per year in fare revenue (one percent of operating costs).

Air Quality Impacts

Alternative 1 improvements to the existing Franklin Line, including the operating of faster express service, would reduce regional emissions by 0.03 percent (see Table G-35). This is fourth-largest air quality benefit that could be achieved through the operation of express service on existing lines (after the Haverhill/Reading, Lowell and Rockport/Ipswich lines).

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[16] This cost does not include the relocation of the layover to Bellingham. This is considered to be part of the cost of the "existing line improvements."

The capital cost per kilogram of VOC eliminated per day would be $1,724,000. This is in the mid-range of comparable costs for service improvements to existing commuter rail lines.

Table G-35
Air Quality Impacts of Franklin Line Improvements

	% Reduction Regional Emissions	Capital Cost/kg of VOC Elim/weekday
Existing Line Improvements	0.03%	$1,724,000
Milford Extension	0.03%	$3,212,000
Foxborough Extension	0.02%	$1,368,000

The Milford and Foxborough extensions would achieve similar regional emissions reductions (0.03 percent, and 0.02 percent, respectively). However, nearly all of the benefits would result from new ridership attracted to existing stations by improved service assumed in conjunction with the extensions. The air quality benefits gained through new ridership on the extensions themselves would be insignificant.

Conclusions

The operation of faster service, including more express trains, on the existing Franklin Line would generate significant ridership increases (up to 2,580 total trips and 1,245 new transit trip per weekday). Further, these improvements could provide modest air quality benefits (a 0.03 percent reduction in regional emissions). However, the level of service assumed for the analysis appears to be excessive for the amount of ridership gained. As a result, the farebox return would be lower (24 percent) than those of improvements on several other lines. It is probable that most of the ridership increase could still be attained with smaller, less costly service improvements. Subsequent, more detailed analysis of this line should focus on such a strategy. At the assumed level of service, the capital cost per new weekday rider ($36,800) would be in the mid-range for improvements to existing commuter rail lines.

Both of the extensions—Milford and Foxborough—would attract few new riders and provide few air quality benefits. The costs of these extensions, both operating and capital, would be very high relative to the benefits received.

Attleboro/Stoughton Line Improvements

Existing Service

Currently, two branches of the Attleboro/Stoughton Line serve 13 stations (see Figure G-22). Commuter service on the Attleboro Line (part of Amtrak's Boston–New Haven Main Line) operates between South Station and Providence, Rhode Island. Service on the Stoughton Branch operates between South Station and Stoughton, diverging from the Attleboro Line at Canton Junction. The Attleboro/Stoughton Line is the most heavily used of all MBTA commuter rail lines, carrying 16,200 trips per weekday in April 1992. This is almost double the ridership on the next most heavily used line (8,500 per weekday on the Franklin Line). There are several reasons for the high ridership on this line:

(1) Faster service is operated on this line than others. The Main Line to Providence is maintained for speeds of up to 100 mph for Amtrak intercity service; MBTA commuter service on this line operates at maximum speeds exceeding 80 mph (versus maximum speeds of 60 mph on other lines). As a result, travel times from longer distances are shorter on the Attleboro Line than on other lines.

(2) A planned extension of Interstate Route 95 between Route 128 in Canton and Boston was canceled. As a result, automobile access to Boston from areas served by the Attleboro/Stoughton Line is not as good as from many other parts of the region.

(3) The combination of faster commuter rail service and more difficult automobile access to Boston provides a travel time advantage for commuter rail trips over automobile trips from many areas served by the Attleboro/Stoughton Line. (The Franklin Line is the only other MBTA commuter rail line with a time advantage compared to automobiles.)[17]

(4) There are large numbers of trips to downtown Boston (more than 500 each) from all of the communities directly served by the line.

During the AM peak, there are six inbound trains on the Attleboro Line. Four of these operate from Providence and two from South Attleboro. Headways from Providence are 20 to 60 minutes. From South Attleboro, they are 20 to 43 minutes. From the terminal in, most trains make all stops except Hyde Park and Ruggles. On the Stoughton Branch, there are four inbound trains, with 29 to 43 minute headways. Three of these make all stops except Ruggles; one makes all stops.

Mid-days, a combination of Attleboro Line and Stoughton Branch service is run. Headways on each line range from about one hour to over three hours.

During the PM peak, four trains operate to Providence, one to South Attleboro, four to Stoughton, and two to Canton Junction. Headways are 30 to 50 minutes on Attleboro Line trains, and 30 to 45 minutes on Stoughton Branch trains.

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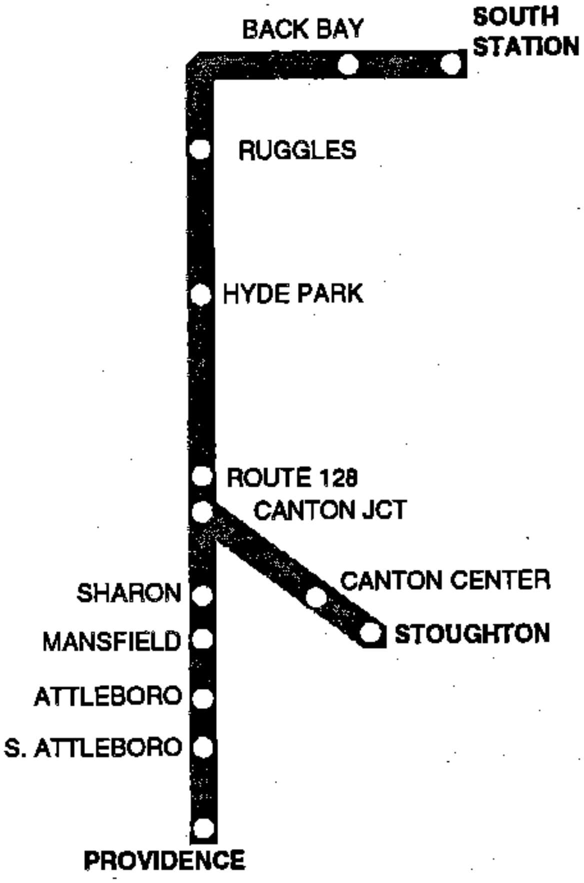
[17] Of 1,004 zones in the MAPC region analyzed for the PMT, door-to-door travel times to downtown Boston were faster by commuter rail than by automobile only from sections of Sharon, Canton, Randolph, Hyde Park, Franklin, Walpole, Norwood, Westwood, and Dedham.

Figure G-22
Attleboro/Stoughton Line Service



PMT Alternatives

For the PMT analysis, two service improvement alternatives were examined:

1. A combination of faster running times and express service on the existing lines.
2. An extension of the Stoughton Branch to Fall River and New Bedford.

1. Express Service with Higher Maximum Speeds

The first alternative involves service changes to the existing lines. These include the operation of revised express service on the Attleboro Line, and all-local service on the Stoughton Branch.

All peak period service on the Attleboro Line would run express between Sharon and Ruggles. This would be similar to the current service configuration, but Route 128 and Hyde Park stations would be served only by Stoughton Branch trains. (The more limited service on the Attleboro Line will be necessary to avoid scheduling conflicts between commuter trains on that line and planned Amtrak high-speed intercity service.) Stoughton trains would make all stops. Service on both lines would operate at 30-minute headways.

Figure G-23
Express/Local Service Configuration

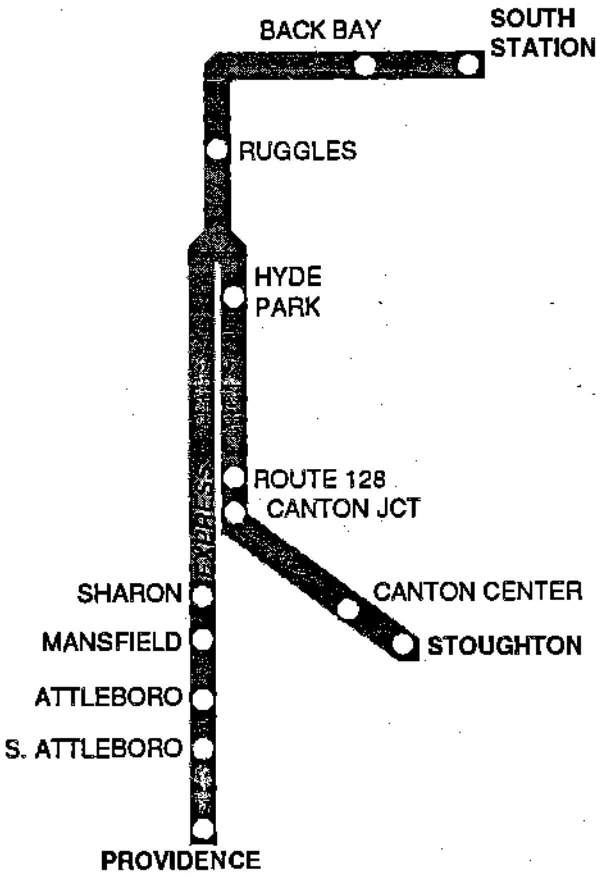


Table G-36
Faster Attleboro/Stoughton Line Service:
Attleboro Line Travel Times to South Station (in minutes)

	Existing Local	Existing Express	Future Express	Future Local
Providence	69	59	58	—
S. Attleboro	60	50	47	—
Attleboro	53	40	39	—
Mansfield	44	30	31	—
Sharon	34	25	22	—
Stoughton	37	—	—	35
Canton Center	33	—	—	30
Canton Junction	29	—	—	27
Route 128	24	—	—	21
Hyde Park	19	—	—	15
Ruggles	9	—	9	9
Back Bay	5	5	4	4

Resulting service levels would be similar to current ones. Present schedules would be retained during off-peak hours.

The operation of service in this manner would have relatively little impact on running times compared to present express service (see Table G-36). More trains would be run at express speeds, however. There would also be slightly higher peak-period service levels from stations served by the Stoughton Branch.

2. Service to New Bedford and Fall River

The second alternative for this corridor consists of an extension of the Stoughton Branch to New Bedford and Fall River. This would be a reinstitution of service that was discontinued in 1958, when the number of Boston commuters living along the line was much lower. Between Stoughton and Whittenton Junction in Taunton, the rail line is abandoned, and mostly dismantled, but the right of way is owned by the MBTA. Beyond Whittenton Junction, all the rail lines involved are still used for freight service. Some segments are owned by EOTC and the remainder by Conrail.

The PMT analysis was based mainly on the results of a feasibility study of potential rail extensions beyond Stoughton completed for the MBTA in 1990.[18] Five alternatives were analyzed in that study. These were:

1) To Whittenton Junction via the abandoned Stoughton Branch right of way, continuing to East Taunton via the New Bedford Branch. New stations on this extension would be located on the Stoughton/Easton town line, at the Raynham Dog Track, in downtown Taunton, and at East Taunton. Alternatives 2 through 5 would all be further extensions of Alternative 1.

2) To East Taunton as in Alternative 1, continuing to New Bedford via the New Bedford Branch and New Bedford Secondary Track. The only station other than those included in Alternative 1 would be in downtown New Bedford.

3) To East Taunton as in Alternative 1, continuing via the New Bedford Branch and New Bedford Secondary Track to Myricks in the town of Lakeville, then to Fall River via the Fall River Secondary Track. Along with the stations included in Alternative 1, Alternative 3 would have stations in Freetown and in downtown Fall River.

4) A combination of Alternatives 2 and 3, with service to both Fall River and New Bedford, and including a Freetown Station.

5) Via the same alignment as Alternative 1 as far as Nash Road in New Bedford, then via the Dartmouth Industrial Track to a point in Westport near the Fall River city limit. This alignment would not reach the downtown areas of either New Bedford or Fall River. New Bedford would be served by a station near King's Highway. Fall River would be served by the terminal station in Westport. There would also be a station in Dartmouth.

The study assumed that under Alternative 1, East Taunton service would replace existing Stoughton Branch service. Because of running time considerations, it was assumed that under Alternatives 2 through 5, peak service on the extension would be in addition to existing Stoughton service, and would not stop at any of the present stations between Easton and downtown Boston. Off peak-service would replace Stoughton trains, as in Alternative 1.

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[18] Commuter Rail Extension Feasibility Study New Bedford Fall River Final Report, January 1990. Prepared by Louis Berger & Associates, Inc., Gordon Bus & Read, Inc., Multisystems, Inc., Carol R. Johnson & Associates, Inc. K&M Associates.

For the PMT analysis, capital costs in the 1990 study were updated for consistency with other PMT projects. The ridership projections in the study were prepared by CTPS, and are therefore consistent with other PMT estimates. Alternative 4, which had the highest projected ridership of the five extensions, was used in comparing this project with other PMT projects. (See Figure G-24.)

Ridership Impacts

The operation of express trains on the Attleboro/Stoughton Line would increase ridership by 525 trips per weekday. Most of this increase (490 trips) would be new transit trips. Nevertheless, this would rank seventh of the eight potential commuter rail express service projects in new riders attracted.

Table G-37
Ridership Impacts of Attleboro/Stoughton Line Improvements

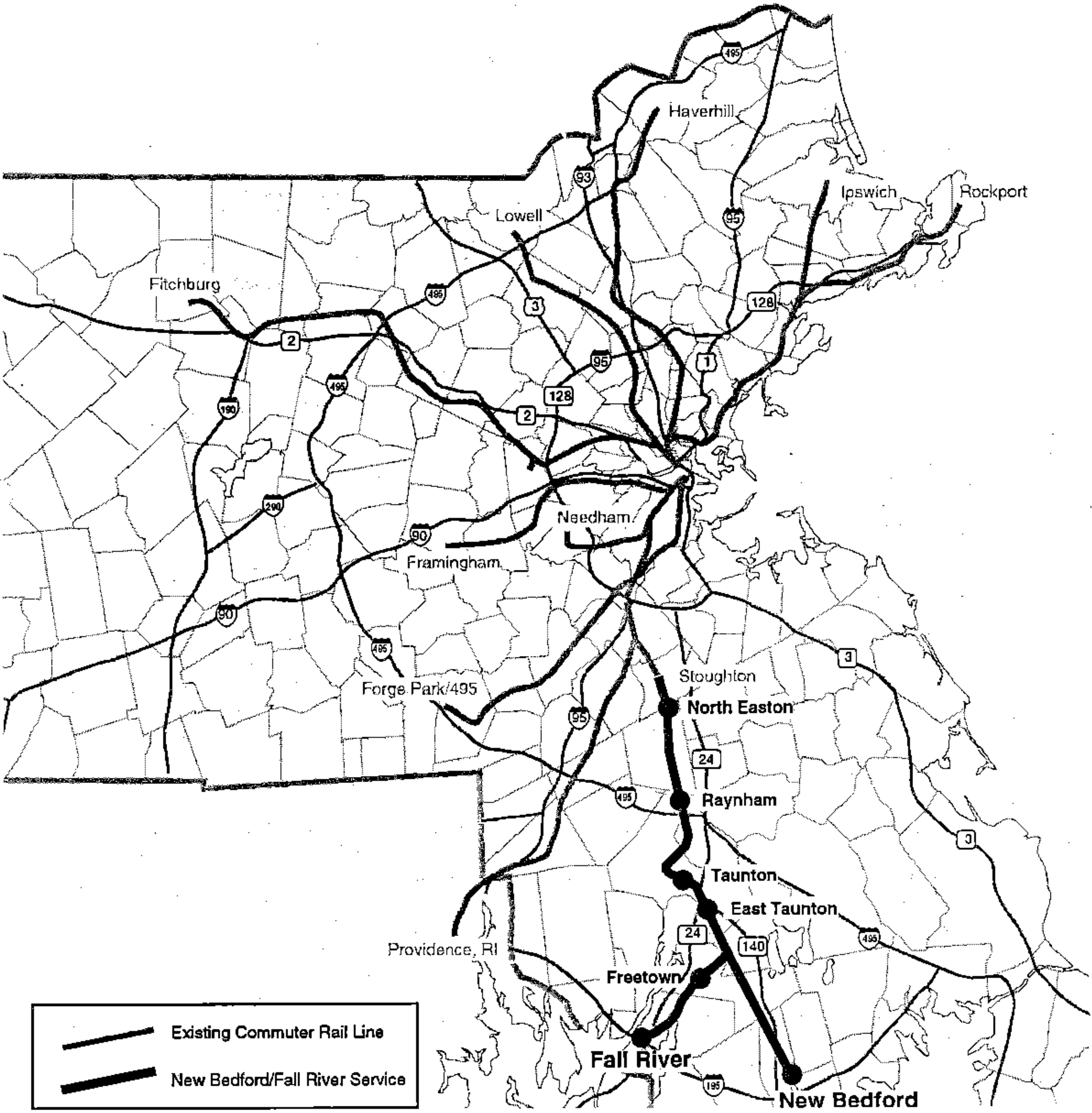
	Total Trips	New Transit Trips
Attleboro/Stoughton Line Express Service	525	490
New Bedford/Fall River Service	6,465	2,820

A commuter rail extension from Stoughton to New Bedford and Fall River (1990 Study Alternative 4) would serve an estimated 6,465 riders a day in 2020, including 2,820 new transit riders. This is the largest ridership total and second largest number of new transit riders on any commuter rail extension or improvement examined for the PMT. (The Old Colony Lines restorations will carry more riders, but were not analyzed for the PMT because they are already committed and under construction.) By station, ridership on a New Bedford/Fall River extension would be as follows:

North Easton	1,785
Raynham	555
Taunton Center	600
East Taunton	1,155
New Bedford	1,140
Freetown	630
Fall River	600
Total	6,465

The demand forecasts indicate that 3,645 of the riders on the New Bedford/Fall River extension (1,822 in each direction) would be diverted from the present express bus routes in the area. It was assumed that without the rail extensions, bus frequency would be increased

Figure G-24
New Bedford/Fall River Commuter Rail Service



as needed to meet demand in 2020, but that the bus routes would be discontinued if rail service were implemented. The estimates do not take into account diversions from either present Attleboro or Stoughton Line stations or Old Colony Line stations that will be in operation by 2020. Such diversions would make the number of new transit riders less than the 2,820 stated above.

An extension only as far as East Taunton (Alternative 1) would serve 3,870 riders a day, including 2,265 new transit users. This would be 60 percent of the total rail riders and 80 percent of the new transit riders served by the full extensions (Alternative 4) but would require only 38 percent as many new route-miles. Taking into account both rail and bus ridership, transit ridership south of Stoughton with the East Taunton extension alone would be 85 percent of that in Alternative 4.

Compared to present bus schedules, peak-period rail service running express north of Easton would reduce travel time from New Bedford to Boston by 17 minutes (19 percent). Travel time from Fall River would, however, increase by ten minutes (15 percent), because the rail route from Fall River is less direct than the bus route and includes more intermediate stops. Future increases in highway traffic congestion could give rail service a greater advantage.

Costs and Cost-Effectiveness

Operation of express service on the Attleboro Line would not require any track or signal improvements. This line is part of Amtrak's Boston–Washington Northeast Corridor, and is already maintained for much higher operating speeds than those of any other MBTA commuter rail line. To provide the acceleration characteristics required to provide the travel times in Alternative 1, it would be necessary to use two locomotives on each train instead of one as at present. This would require nine additional locomotives, at a cost of $20.8 million. This would result in a capital cost per new transit rider of $42,400. This is much higher than the comparable costs for service improvements on the Rockport/Ipswich, Haverhill/Reading and Lowell Lines, and slightly above that for the Franklin Line. Some expansion of parking capacity or increases in train lengths might also be required to accommodate additional riders attracted by the new service. Costs for these have not been estimated, as they would require a more detailed analysis of capacity constraints on the system.

Express service on the Attleboro Line would increase operating costs by $847,000 per year. Revenue would increase by $275,000. The farebox recovery rate would be 32 percent. This compares favorably with the existing system, and is higher than the ratios for most of the other potential commuter rail express services examined.

The restoration of commuter rail service to New Bedford and Fall River would require total reconstruction of 15.8 miles of abandoned line between Stoughton and Whittenton Junction. Extensive upgrading of 28.3 miles of track between Cotley Junction and New Bedford and Fall River, now used only for local freight service, would be needed to meet passenger service standards. The remaining 3.8 mile segment between Whittenton Junction and Cotley Junction is part of Amtrak's summer weekend route from New York to Cape Cod. It was upgraded for this service in 1986.

The New Bedford/Fall River extension would also require construction of seven new stations and two layover facilities. (Platform length and parking capacity at the Amtrak Taunton station are inadequate for commuter service.)

The most recent capital cost estimate for extension of commuter rail service to both New Bedford and Fall River (Alternative 4) is $288 million. This exceeds the cost of any commuter rail project examined for the PMT except for the North-South Rail Link. The capital cost per new weekday rider would be $102,100. This would make it one of the less cost-effective commuter rail projects examined. (None of the more costly projects are included in the recommended program.) Operating costs would increase by $12.2 million per year, while revenue would increase by $2.6 million. This would result in a relatively low revenue to cost ratio of 22 percent.

An extension to East Taunton only (Alternative 1) would be much more cost-effective than Alternative 4. If operated by extending existing Stoughton trains through, with capacity expanded as needed to meet demand, Alternative 1 would have total capital costs of $122 million. The capital cost per new rider would be $58,863. This is higher than the costs per rider for the Worcester and Newburyport extensions, but lower than that of a Millis extension. Operating costs would increase by $4.37 million per year, compared to a revenue increase of $1.5 million. This would be a revenue to cost ratio of 34 percent, and would exceed that of any other commuter rail extensions examined in the PMT except for a Newburyport extension (75 percent) and a Worcester extension (63 percent).

The 1990 study did not include calculations of travel time savings for any of the alternatives. Therefore, unit costs related to this measure cannot be compared with those for other PMT projects at present.

Table G-39
Cost-Effectiveness of Attleboro/Stoughton Line Improvements

	Operating Cost (Annual)	Fare Revenue (Annual)	Capital Cost	Capital Cost per New Trip
Attleboro Line Express Service	$0.8m	$0.3m	$20.8m	$42,400
New Bedford/Fall River Extension	$12.2m	$2.6m	$288.0m	$102,100
East Taunton Extension	$4.4m	$1.5m	$122.0m	$58,900

Air Quality Impacts

The operation of express service on the Attleboro Line would reduce regional emissions by 0.01 percent. The capital cost per kg of weekday VOC eliminated would be $1,784,770. Service improvements on six of the seven other existing commuter rail lines would have larger air quality impacts. On five of these, the costs per unit of air quality improvement would be lower.

A New Bedford/Fall River extension would have larger air quality benefits than any other commuter rail extension examined in the PMT. Regional emissions would be reduced by 0.10 percent. The cost to attain this would also be relatively high, at $3.5 million per kg of weekday VOC elimination. An extension to East Taunton only would have smaller total air quality benefits, reducing weekday emissions by 0.06 percent. This would still compare favorably with most of the other commuter rail projects. The cost per kg of weekday VOC elimination, $2.36 million, would be relatively low for a rail extension and similar to that of the Millis line.

Table G-38
Air Quality Impacts of Attleboro/Stoughton Line Improvements

	% Reduction Regional Emissions	Capital Cost/kg of VOC Elim/weekday
Attleboro Line Express Service	0.01%	$1,785,000
New Bedford/Fall River Extension	0.10%	$3,459,000
East Taunton Extension	0.06%	$2,356,800

Conclusions

The expansion of express service on the Attleboro Line would generate fewer new trips per day (525) than most other commuter rail projects examined for the PMT. Resulting air quality improvements would likewise be limited (a 0.01 percent reduction in weekday emissions). The capital costs per unit of air quality improvement would exceed those for improvements on four other commuter rail lines for which total emission reductions would be larger. Incremental revenue would cover a relatively high 32 percent of incremental operating costs. Regardless of benefits to commuters, planned increases in high-speed intercity service on this line will require speeding up of commuter trains to avoid scheduling conflicts.

An extension of commuter rail service to New Bedford and Fall River via the Stoughton Branch would attract more total riders (6,465) than any other commuter rail extension examined for the PMT. It would attract more new transit riders (2,820) than all but the Worcester extension. It would, however, require a large capital investment ($288 million) because of the lengths and present conditions of the line segments involved. It would be one of the less cost-effective commuter rail projects in capital cost per new weekday rider ($102,000) and per kg of weekday VOC elimination ($3.5 million.) The ratio of revenue to operating cost (21 percent) would fall short of the system standard.

The largest part of the ridership on a New Bedford/Fall River extension (3,870 total and 2,265 new transit riders) could be attracted by an extension running only as far as East Taunton. This would be much more cost-effective than the full extensions. Capital cost would be reduced to $122 million. The ratio of revenue to operating cost would rise to 34 percent, which compares favorably with the existing system.

Greenbush Old Colony Line

This section summarizes the results of the PMT analysis of restoration of commuter rail service between Boston and Greenbush Station in Scituate. This project has been studied extensively as part of the Environmental Impact Report for the Old Colony Railroad Rehabilitation Project. The PMT numbers are based on information in that report, except where additional calculations were needed to allow comparisons with other PMT projects. It should be noted that the Greenbush Line has been treated as a base-case service. The original demand estimates for this line were for the year 2000, and they have not been updated to year 2020 as projections for most other PMT projects were.

Existing Service

At present, there is no direct commuter rail service to South Shore communities. Until 1959, this region was served by three New Haven Railroad routes that were once part of the Old Colony Railroad system. These consisted of a main line from Boston to Middleborough and Cape Cod, with branches diverging at Braintree to Greenbush Station in Scituate, and at South Braintree to Plymouth.

The most heavily traveled part of the Old Colony system was replaced by the South Shore Branch of the MBTA Red Line, which runs along the former Old Colony alignment for most of the way from Boston to Braintree Station. Other South Shore communities are now served by a combination of MBTA and private-carrier feeder bus service to the Red Line, private-carrier express buses to downtown Boston, and commuter boat service from Hingham to Boston.

Suburban population growth and increasing commuting distances resulted in revitalization of the Boston commuter rail system starting in the mid 1970s. This, in turn, prompted efforts to reinstate South Shore commuter rail service. The MBTA has recently begun rehabilitating the Old Colony Lines to Plymouth and Middleborough for this purpose. A final decision on restoration of Greenbush service is awaiting completion of further environmental impact studies.

PMT Alternative

The PMT alternative for this corridor is a restoration of commuter rail service on the Greenbush Branch in addition to the other two Old Colony branches. Greenbush trains would use the same tracks as Plymouth and Middleborough trains for the first 10.1 miles out of South Station. The Greenbush Branch right of way diverges at the former Braintree Station site (between the present Quincy Adams and Braintree Red Line Stations) and runs for 17.6 miles through the towns of Weymouth, Hingham, Cohasset, and Scituate to Greenbush.

The segment from the junction in Braintree to East Braintree Station is owned by Conrail and is still used for freight service. The rest of the branch is abandoned and partly dismantled. The segment from East Braintree to Nantasket Junction in Hingham (seven miles) is owned by EOTC. Ownership of the remainder is divided among the state Department of Environmental Management and the towns of Cohasset and Scituate. No structures have been built within the right of way, but several segments are used for parking or for access to adjacent property.

A restored Greenbush Branch would have seven stations, at Weymouth Landing, East Weymouth, West Hingham, Nantasket Junction, Cohasset, North Scituate, and Greenbush (see Figure G-25). Of these, Weymouth Landing (formerly Weymouth Station), East Weymouth, North Scituate and Greenbush would be on or near the sites of stations used until 1959. West Hingham and Nantasket Junction would be on the sites of stations discontinued many years earlier. The Cohasset Station would be at a new location east of the Hingham town line. Previous service included stations in the business centers of Hingham, Cohasset and Scituate, but the new service would not.

As currently proposed, Greenbush trains would run non-stop between Weymouth Station and Boston. Plymouth and Middleborough trains will stop at the Braintree Red Line Station, but the Greenbush route does not run past this location. If a commuter rail station were provided at any Red Line stop between Quincy Adams and JFK UMass, inclusive, Greenbush trains would be able to use it.

Ridership Impacts

The Old Colony EIR includes ridership projections only for weekday AM peak inbound trains for the year 2000. Ridership for all other PMT projects was calculated in the form of two-way all-day boardings and alightings in the year 2020. The EIR indicates that for the no-build alternative, (i.e., with none of the three Old Colony branches) 76 percent of inbound weekday transit ridership from the South Shore would occur in the AM peak.

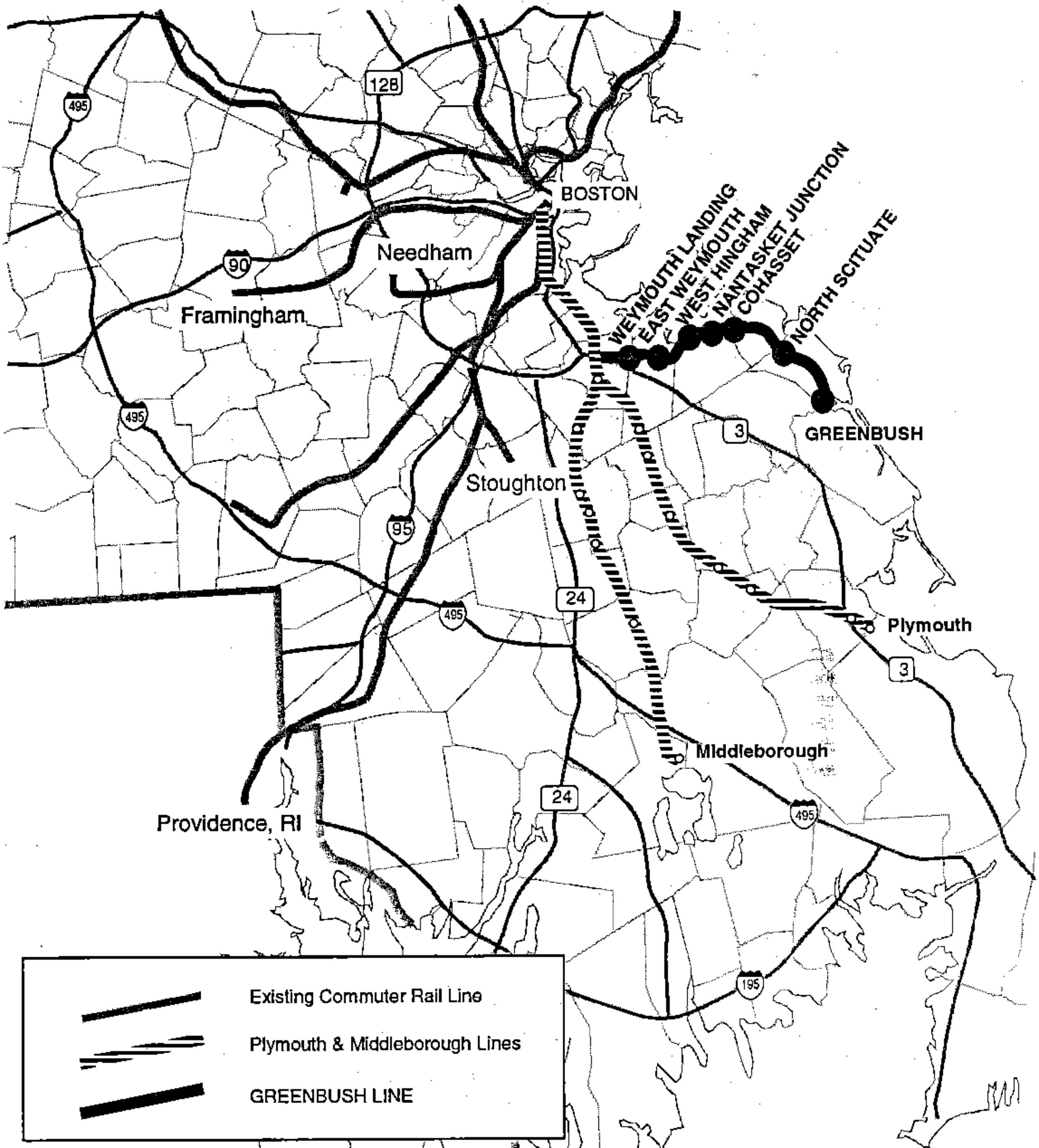
More than half of the base-case transit ridership would be on the Red Line, which has lower peaking than commuter rail. On most South Side commuter rail lines, inbound AM peak ridership accounts for about 80 percent of the inbound daily total. Using an 80 percent inbound peaking factor, the Greenbush Branch projections would expand to a two-way daily total of 8,350 riders in 2000. (There would be additional ridership growth between 2000 and 2020, but this has not been estimated.)

The EIR forecasts indicate that 58 percent of the passengers on the Greenbush Branch would be new transit users. This would be 4,830 two-way weekday riders. This is the largest number of new transit riders of any commuter rail project examined in the PMT, except for the North-South Rail Link. The remainder would be diverted from other transit services that would be operated in the base case. These include the Hingham commuter boat, the Red Line, express buses, and the other two Old Colony branches. The commuter boat would be affected most, accounting for 40 percent of the transit diversions, and losing 44 percent of its riders.

Costs and Cost-Effectiveness

Reinstitution of commuter rail service on the Greenbush Branch would require reconstruction of the entire line. (Some segments have been abandoned for as long as 30 years.) In the past, there was little or no off-street parking capacity at stations. The station plans in the Old Colony EIR would include parking for 200 to 800 cars at each station, for a total of 2,735 spaces. The EIR plan calls for five train sets, with an average length of four double-deck cars per train, to serve the line. Total capital costs for construction and rolling stock, in 1991 dollars, would be $111,140,000. This includes costs for land taking (mostly at stations) but these costs were not shown separately.

Figure G-25
Greenbush Line



The main issue delaying a decision on implementation of the Greenbush Branch is the impact on Hingham Center. One option for reducing this impact is to place the line in a tunnel there. (A tunnel under downtown Salem on the Rockport/Ipswich commuter rail line provides a precedent.) The cost of a tunnel at Hingham is not included in the total above. This cost would depend on several factors, including the length, depth below surface, and construction method. An informal estimate of $60 million has been used in some discussions of the project. This would be an increase of over 50 percent in total project cost.

Capital costs for the Greenbush Branch could be partly offset by a $6.4 million reduction in purchases of buses and construction of park-and-ride lots that the EIR assumed would be needed if the branch was not restored. These would not be entirely MBTA expenses however, as service in the area is operated predominantly by private carriers, and is not all subsidized. Excluding this offset, and the possible cost of a Hingham tunnel, the Greenbush Branch would have a capital cost per new weekday transit rider of $23,010. This is much lower than for any other commuter rail extension examined in the PMT, even disregarding additional ridership growth from 2000 to 2020.

The annual operating cost for the Greenbush Line, with service seven days a week would be $6,495,000.[19] Annual fare revenue from new transit riders would be $3,186,000. This would make a revenue to cost ratio of 49 percent. It would exceed that of any other commuter rail extension examined in the PMT except for Newburyport and Worcester extensions.

Air Quality Impacts

Air quality improvements from the Greenbush commuter rail extension would be among the largest for all PMT projects. Regional emissions would be reduced by 0.10 percent. The only commuter rail extensions with equal reductions would be those to Worcester and New Bedford/Fall River. The capital cost per kg of weekday VOC elimination ($1.31 million) would be lower than those of most commuter rail extensions examined for the PMT, if the line can be built without a tunnel at Hingham Center.

Conclusions

Restoration of commuter rail service on the Greenbush Branch compares very favorably with other PMT projects in all measures examined. It would attract more new transit riders (4,830) than any other commuter rail extension. (The Greenbush ridership projection is for the year 2000, and is therefore understated.) If the Greenbush Branch can be rebuilt without a tunnel at Hingham Center, the capital cost per new rider would be $23,010. This is less than the comparable cost for any other PMT commuter rail extension. Revenue from new transit riders would cover 49 percent of operating costs, exceeding the ratios for all commuter rail extensions except Newburyport and Worcester. The Greenbush Line would have comparatively large environmental benefits, reducing regional emissions by 0.10 percent.

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[19] The EIR assumed that service on the Greenbush Line would run Monday through Saturday. When the study was done, there was no South Side commuter rail service on Sundays, but such service is now being run on most lines on a trial basis.

Bus Service Improvements in/to Downtown Boston

This section summarizes the results of the PMT analysis of providing better bus service to and from, and better bus distribution in, downtown Boston.

Existing Conditions and PMT Alternatives

Bus service is impacted by traffic congestion in a similar manner as automobile traffic. However, because of frequent passenger stops, bus travel times are much longer. To make bus and HOV travel times more competitive with single-occupancy automobile travel times, the institution of bus/HOV lanes was considered for a number of congested locations:

- On the new Central Artery and access roads to and from the new third harbor crossing.
- On the Southeast Expressway.
- Between the Mass Pike and the Financial District along the Surface Artery and High Street to Federal and Franklin Streets.
- On Rutherford Ave, through City Square and on the Charlestown Bridge.
- On Washington Street in Roxbury, the South End, and/or downtown Boston.
- HOV lanes and free or reduced toll passage on the Massachusetts Turnpike, through the Sumner Tunnel, and across the Tobin Bridge.

The placement of HOV lanes on the new Central Artery, to and from the Third Harbor Crossing, on the Southeast Expressway, and on I-93 north is being addressed as part of broader HOV studies. Also, the operation of transit service on Washington Street is being addressed within the context of Washington Street replacement service. The PMT analysis focused on the potential for bus/HOV lanes through City Square in Charlestown, in the Financial District, and to and from the Sumner Tunnels.

Bus/HOV Lanes through City Square

At the present time, three MBTA bus routes—92, 93, and 111—are scheduled to operate through City Square. However, due to congestion on I-93 and on Route 1, City Square is also frequently used as an alternate route by I-93 express buses (Routes 325, 326, 352, and 353/354), and by one North Shore express route (426). All of these routes have frequent peak-period service. In addition, the Charlestown Bridge is heavily used by private buses and shuttles. Counts conducted in 1988 showed at total of 75 buses traveling across the bridge between 4:00 and 5:00 pm, and 87 between 5:00 and 6:00 pm.

The CANA and CA/T projects will significantly change existing traffic conditions on approaches to downtown Boston from the north. These projects will add three lanes of capacity to the Charles River crossing. This will effectively eliminate the river crossing as a significant bottleneck. At the same time, no capacity will be added to I-93 north in Medford and Stoneham. This section, which is nearly full today, will become completely full in the future with the Charles River bottleneck removed. In effect, the current bottleneck at the

Charles River crossing will be converted to a longer stretch of congested traffic between Route 128 and Medford.[20]

In addition, the Central Artery southbound off-ramp at Haymarket that is now used by express buses will be eliminated. This will require I-93 and Route 1 express buses to be rerouted along one of three routes:

(1) via the Storrow Drive exit through a new Leverett Circle interchange to Nashua Street and Congress Street. As currently planned, this exit would not be accessible from the I-93 HOV lane.
(2) via the Clinton Street off-ramp and then back to Haymarket along Congress Street. This would be the first exit accessible from the I-93 HOV lane.
(3) via the City Square exits from I-93 and Route 1 south through City Square and over the Charlestown Bridge and along North Washington Street. This exit would not be accessible from the I-93 HOV lane but would be accessible via a service road that would provide a similar level of service as the HOV lane.

Travel times along the three routes have not yet been determined by the Central Artery team. However, the route through City Square appears be the most direct for I-93 and Route 1 express buses. Current projections indicate that this route will not be congested, so that a southbound HOV lane in this area would provide little benefit.

In the PM, the I-93 northbound queue is projected to occur in Somerville at the Mystic Avenue on-ramp. Significant congestion is not expected through City Square, and as with the opposite direction, an HOV lane through City Square would provide few travel time benefits. However, one significant difference in the northbound direction is that buses will be able to directly enter the Central Artery from New Sudbury Street to I-93 north. Therefore, if a northbound HOV lane were constructed from downtown Boston past the bottleneck point in Somerville and Medford, and if it could be accessed from the New Sudbury on ramp, I-93 bus service would benefit.

Bus Loops through Downtown Boston

Most existing express and local bus services from Boston neighborhoods and suburbs provide only limited distribution in downtown Boston. Service is operated in this manner so that buses avoid downtown traffic congestion that could adversely affect on-time performance. However, by avoiding much of downtown, the markets that are directly served are smaller, and ridership is presumably lower than it otherwise might be. (In contrast, many private-carrier bus services to and from downtown Boston do provide some sort of distribution in downtown areas.)

At present, 23 MBTA routes (as listed in Table G-40) provide service into downtown Boston.[21] All local routes except Route 111 provide some circulation within downtown Boston (see Figure G-26). Routes 92 and 93 operate to and from Downtown Crossing during working hours, South Boston routes and Route 49 operate along a variety of alignments in or near the Financial District, and Routes 43 and 55 circle the Boston Common. Route 111,

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[20] CTPS Technical Memorandum "Preliminary Benefit/Cost Analysis for Possible Northerly CA/T HOV Facilities Located Along I-93 North and the Central Artery between Somerville and Downtown Boston," Tom Lisco, December 2, 1992.

[21] In addition, a number of private carriers also provide service into downtown. These services are not explicitly addressed herein, but it is assumed that private services would also be permitted to use the same bus lanes.

Table G-40
MBTA Route Operating To and From Downtown Boston

From Charlestown and Chelsea
Route 92 Assembly Square Mall – Downtown via Sullivan and Main St.
Route 93 Sullivan Square – Downtown via Bunker Hill St.
Route 111 Woodlawn – Haymarket

I-93 Express Routes
Route 325 Elm Street, Medford – Haymarket via I-93
Route 326 West Medford – Haymarket via I-93
Route 352 Burlington – Downtown Boston via Route 128 and I-93
Route 353/354 Burlington Industrial Area/Woburn Line – Downtown

North Shore Express Routes
Route 426 Central Square, Lynn – Haymarket via Route 1
Route 441 Marblehead – Haymarket via Paradise Road and Central Square
Route 442 Marblehead – Haymarket via Humphrey St. and Central Square
Route 450 Salem Center – Haymarket via Highland and Western Aves.
Route 455 Salem Center – Haymarket via Loring Ave.

Mass Pike Express Routes
Route 300 Riverside – Downtown Boston
Route 301 Brighton Center – Downtown Boston
Route 304 Watertown Square – Downtown Boston
Route 305 Waltham Center – Downtown Boston

From the Fenway
Route 55 Jersey & Queensberry – Park Street

From South Boston
Route 3 Chinatown – Boston Marine Industrial Park
Route 6 Haymarket – Boston Marine Industrial Park
Route 7 City Point – Downtown Boston
Route 11 City Point – Chinatown

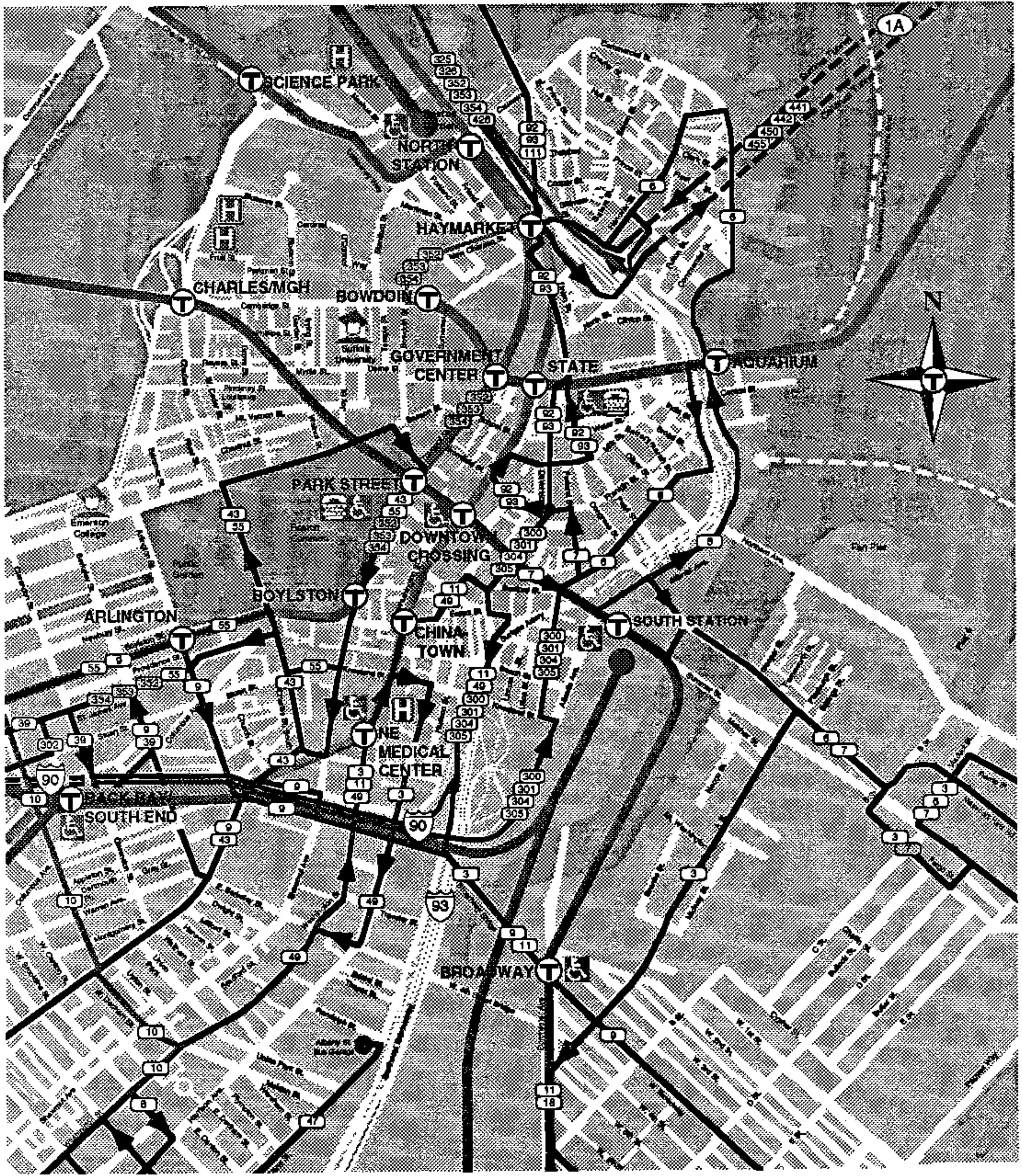
From Roxbury and the South End
Route 43 Ruggles – Park Street via Tremont Street
Route 49 Dudley Square – Downtown via Washington Street

the only local route that does not have downtown circulation, begins and ends at Haymarket.

Downtown circulation on express routes from the north is limited to a few morning trips, and one PM trip, on Routes 352 and 353/354 that operate between Haymarket and Park Square or Copley Square. Nearly all service begins and ends at Haymarket.

Mass Pike express routes operate into the Financial District and have the most extensive downtown circulation of the 23 routes. Of the express services, these routes also have the highest ridership—ridership on the second least utilized Mass Pike Route (Route 305) exceeds the Boston-bound ridership on all the express routes operating from the north.

Figure G-26
Existing Bus Service in Downtown Boston



Existing congestion and the configuration of downtown streets provide only limited opportunities for providing better circulation within the downtown area. There are no ideal sets of streets; however, one loop on relatively free-flowing and/or auto restricted streets would be a counter-clockwise loop consisting of:

- Franklin/Bromfield Streets
- Tremont Street
- Boylston/Essex Streets
- High/Federal Streets

Federal Street is currently the terminus for the Mass Pike express routes and, as such, is already heavily used by buses. Between Devonshire Street and Hawley Street, Franklin Street widens and has light automobile traffic and could be used as a terminal point for additional routes. Beyond Hawley Street, Franklin and Bromfield Streets are limited to buses, trucks, and taxis.

Tremont Street has four travel lanes and is rarely congested.

Essex Street has occasional congestion near the intersection with the Surface Artery. However, this street is less congested than Kneeland Street, which would be the only alternative in the same general area.

High Street already has a bus lane, and Federal Street flows well.

All routes operating into downtown could travel around all of a portion of this loop (see also Figure G-27):

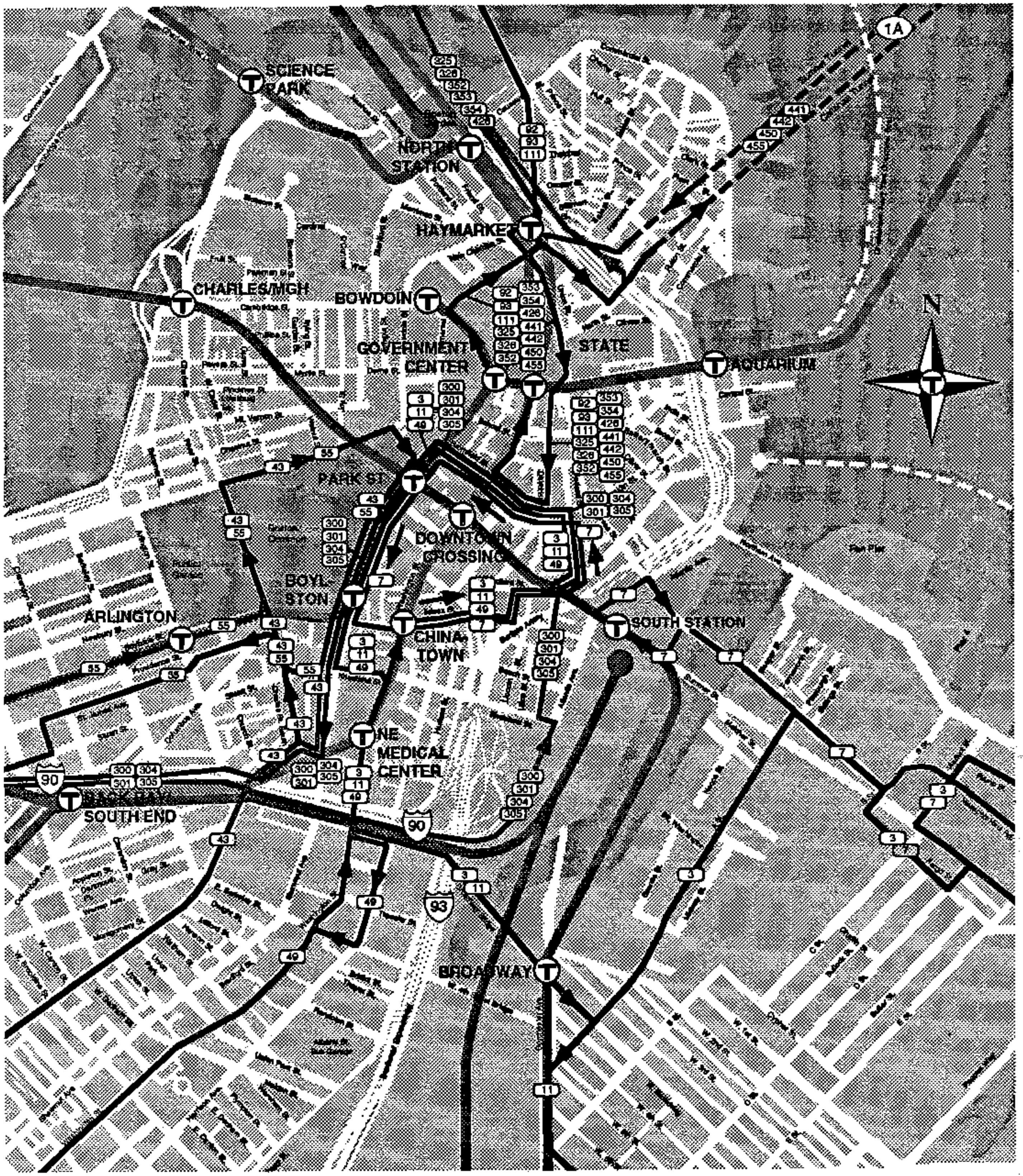
- **Haymarket/Financial District Loop** Routes from the north would travel to the loop from Haymarket via New Congress and Devonshire Streets, then along Franklin Street to Court Street to Cambridge Street, and then via New Sudbury Street back to Haymarket. All peak-period trips would operate around the loop. Off-peak and weekend trips would continue to terminate at Haymarket.

- **Mass Pike/Boston Common Loop** Mass Pike express routes would follow their existing alignments to Federal and Franklin Streets, but then continue on Franklin Street to Bromfield Street to Tremont Street. Buses would then continue along Tremont Street to Marginal Street to the Mass Pike westbound on-ramp at Arlington Street. This loop would replace the current loop and be used for all weekday and weekend service. Travel times to and from the Mass Pike along this alignment would be essentially the same as they are now.

- **Financial District/Chinatown Loop** Routes 3, 11, and 49 from South Boston and Roxbury would enter and exit the loop at Essex Street. Each would depart from its existing inbound alignment at Washington Street at Essex Street where it would enter the loop. From the loop, each would continue past the loop on Tremont Street and then turn left on Stuart Street from where they would rejoin their existing outbound alignment. This loop would replace the current alignments of these routes and be used for all weekday and weekend service. Travel times to and from the Mass Pike along this alignment would be similar to those along each route's existing alignment.

  Route 7 from South Boston would enter and exit the loop at Summer Street. This loop would replace Route 7's existing alignment and be used for all weekday and weekend

Figure G-27
Improved Circulation for Buses Operating to and from Downtown Boston



service. Travel times along this alignment would be similar to those along Route 7's existing alignment.

- **Park Square/Boston Common Loop** Routes 43 and 55 would continue to operate as they now do, looping around Boston Common via Charles, Beacon, Park and Boylston Streets.

Bus Lanes Leading to the Sumner Tunnel

Current Plans for the CA/T project include bus/HOV/taxi lanes leading to the entrances of the new tunnel, but not to the existing Sumner and Callahan tunnels. After construction, the existing tunnels will continue to be used by four North Shore express routes: 441, 442, 450, and 455.

After completion of the CA/T project, the approach to the Sumner Tunnel will be relatively unchanged, but the Callahan approaches will be redesigned to allow access only from the Central Artery southbound and from an on-ramp beginning at Haymarket. Other entrances, including the North Street entrance now used by express buses, will be closed.

At the East Boston end, AM peak congestion extends from the tolls back the length of the East Boston Expressway (to the vicinity of the southbound airport off-ramp). When this occurs, buses normally exit Route 1A and travel local streets (Bremen Street to Porter Street) to the tolls.

To permit buses to bypass this backup without traveling local streets, the left-hand lane of Route 1A could be designated as a bus lane between the southbound airport off-ramp and the tolls. The East Boston Expressway was constructed as a three lane roadway, but is now striped mostly as a two lane roadway in order to provide exclusive lanes to traffic entering from Neptune Street and from the airport (see Figure G-28). Past the Logan off-ramp, the left-hand lane is closed until the Logan on-ramp, where it becomes a general travel lane. To create the bus lane, use of the closed left-hand lane between the Logan off- and on-ramps would be permitted for buses. Past the airport on-ramp, the left-hand lane would be reserved for buses and taxis exiting the airport (also see Figure G-28). It is estimated that this lane would save approximately three minutes per trip in the AM peak.

At the downtown end, there will not be room for a separate bus lane, but it may be possible to provide preferential treatment for buses from Haymarket Station to the tunnel on-ramp. However, at this time there are insufficient data available to project possible travel time savings.

Ridership and Operational Impacts

The provision of better bus distribution in downtown Boston would attract a large number of new riders (up to 7,220 new transit trips per weekday), while a Sumner Tunnel bus lane would attract few new riders (110 per weekday), and virtually all of these riders would shift from the Blue Line (see Table G-41). Better downtown distribution would generate large ridership increases corresponding to the large increases in convenience that would be provided. Conversely, the Sumner Tunnel bus lane would save little time, and thus attract few new riders.

Figure G-28
Bus Lane on Route 1A between Curtis Street and Sumner Tolls

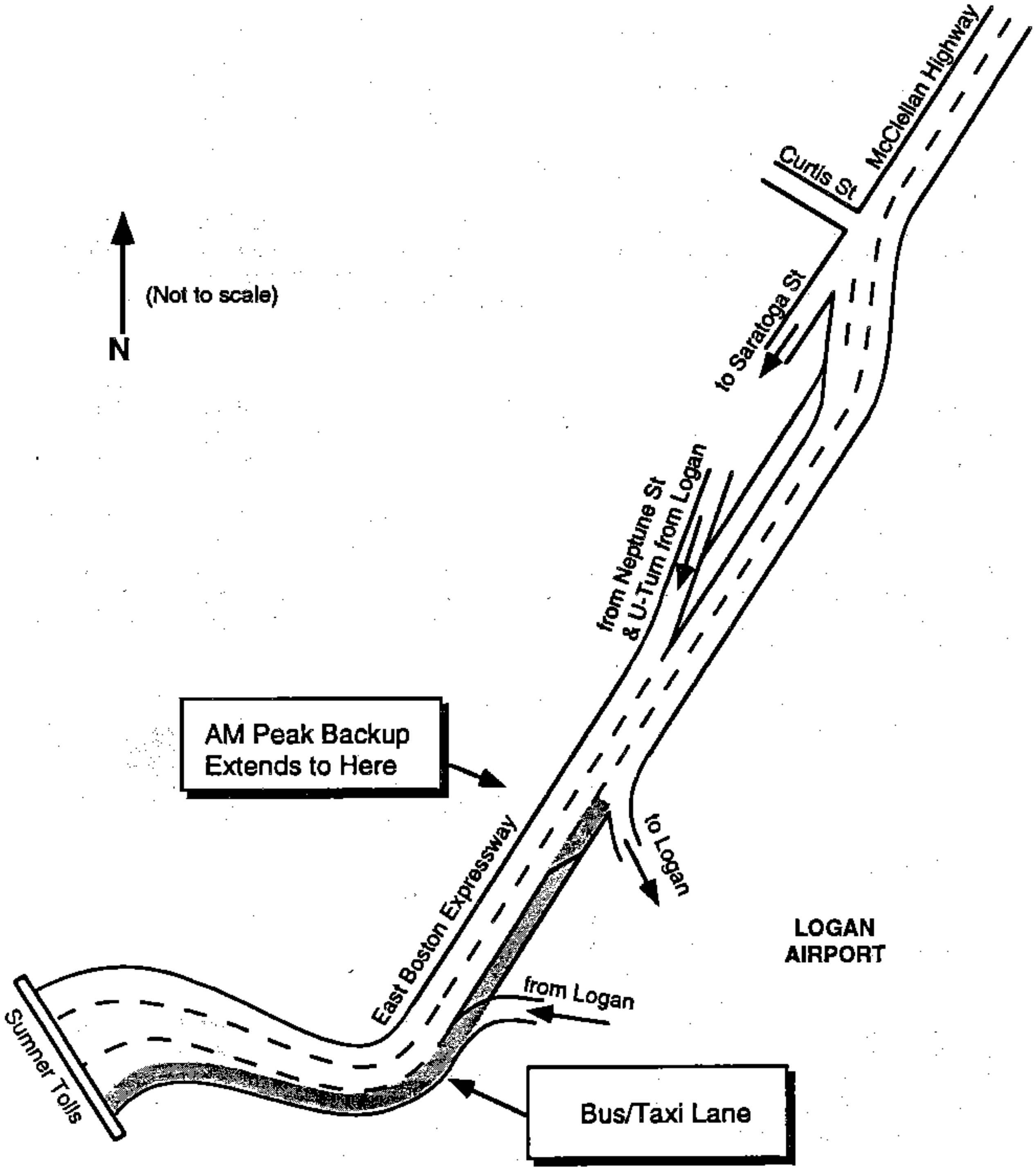


Table G-41
Ridership Impacts of Bus Lanes/Bus Service Improvements

	Total Trips	New Transit Trips
Bus Loops in Downtown Boston	11,880	7,220
Sumner Tunnel Bus Lane	110	0

Bus Loops through Downtown Boston

The operation of all downtown Boston routes through more of downtown Boston would eliminate one transfer or a long walk for many potential riders. This increased convenience would attract up to 11,880 new trips to downtown Boston bus service per weekday. Of these, 7,220 would be new transit trips, and 4,660 would be diverted from other transit services (2,950 from rapid transit, and 1,710 from commuter rail). This would represent a 30 percent increase over current ridership levels. It would also be the third highest number of new transit trips that could generated by any of the PMT alternatives, behind only the North Station - South Station Rail Link and a circumferential LRT line. The elimination of the transfer or long walk would also save a large amount of travel time for existing riders—1,730 hours per weekday, which would be the largest of any PMT bus service project examined.

The PMT analysis was not detailed enough to break down the ridership on a route-by-route basis. However, the VMT savings figures indicate that the average length of trips diverted from automobiles would be over 11 miles. This implies that most of the new trips would be express trips. Further, the greatest increase in downtown service coverage would be for routes operating from the north, and it is believed that a large share of the increase would be on I-93 and North Shore routes.

As described above, the PMT analysis assumed that all peak period bus trips would run through downtown. During peak periods, this would mean changes to approximately 293 to 338 round trips:

	AM Peak	PM Peak
Haymarket/Financial District Loop	150	133
Mass Pike/Financial District Loop	86	71
Financial District/Chinatown Loop	72	69
Park Square/Boston Common Loop	30	20
	338	293

Of these trips, the Haymarket/Financial District Loop bus trips would represent new trips in the downtown area. Trips on the Mass Pike/Financial District and the Financial District/Chinatown loops represent a rerouting of existing service, and not new trips. The Park Square/Boston Common Loop is a continuation of existing service and would not involve changes to service levels or the alignments of routes traveling that loop (Routes 43 and 55). The most heavily utilized portions of the loops would be Franklin Street, High and Federal Streets, and Tremont Street. On Franklin Street, which would be a common segment of three of the four loops, bus traffic would increase from 110 trips in the AM peak to 308 trips. This would increase the number of bus trips 2.8-fold from an average of 0.7 trips per minute to 1.9 trips per minute. On other segments, there would be approximately one bus per minute (see Table G-42).

Table G-42
AM Peak Bus Volumes on Downtown Boston Streets

	Current		Future	
	Trips	Trips/Minute	Trips	Trips/Minute
High and Federal Streets	110	0.7	191	1.2
Franklin Street	110	0.7	308	1.9
Bromfield Street	0	0.0	158	1.0
Tremont Street	30	0.2	188	1.1
Essex Street	0	0.0	144	0.9

A potential negative to this alternative may be the impact on traffic conditions on certain streets. A traffic analysis was not done as part of the PMT analysis, and therefore, traffic impacts on specific streets are not known. Overall, this alternative would remove much more traffic than would be added (the removal of up to 2,850 cars in the AM peak versus the addition of 150 buses). However, localized problems could be caused by the concentration of bus service on certain streets. If subsequent analyses indicate that not all routes could be operated as described above due to adverse traffic impacts, individual routes could still be extended. Further analysis would be required to determine which routes would attract the greatest ridership.

Bus Lanes Leading to the Sumner Tunnel

A bus lane leading to the Sumner Tunnel would save an estimated three minutes per inbound bus trip in the AM peak, and less during other periods of the day. This time savings would not be large enough to divert riders from automobiles to North Shore bus routes 441, 442, 450, or 455, but would result in a shift of a small number of Blue Line riders (110 per weekday).

As with the downtown bus loops, a traffic analysis was not conducted as part of the PMT. However, some conflicts could be expected with traffic entering Route 1A from Logan (where traffic now enters into an exclusive lane). This could cause delays leaving the airport and/or safety problems at the merge. Also, one lane leading to the tolls and one toll booth would be removed from general traffic use.

Costs and Cost-Effectiveness

The provision of better bus distribution in downtown Boston would be relatively inexpensive to operate, and would generate slightly more in fare revenue than the increase in operating costs. A Sumner Tunnel bus lane would also be inexpensive to implement and have no significant operating cost impact. However, because no new transit riders would be attracted, no new fare revenue would be generated (see Table G-43).

Table G-43
Cost-Effectiveness of Bus Lanes/Bus Service Improvements

	Operating Cost (Annual)	Fare Revenue (Annual)	Capital Cost	Capital Cost/ New Trip
Bus Loops in Downtown Boston	$1.3m	$1.3m	$6.1m	$850
Sumner Tunnel Bus Lane	-$0.1m	$0.0m	$0.1m	NA

Bus Loops through Downtown Boston

To operate service through downtown most effectively, bus lanes would be placed on Lincoln, Summer, Federal, and Franklin Streets. This could be done through striping, and would not require significant costs. Because of the high levels of service that would be operated on Franklin Street, some roadway modifications would be needed. Bus shelters would be placed on Franklin Street between Otis Street and Province Street. The total cost of physical improvements would be approximately $100,000.

The greatest expense in providing better distribution would be the additional buses required, principally for the longer North Shore routes. To operate all routes as described above would require 30 new buses at a cost of $6.0 million. This would bring the total cost of better distribution in downtown Boston to $6.1 million. If the MBTA has additional buses available, or if fewer routes were extended into downtown, the capital cost would be lower. However, at $6.1 million, this project would still be one of the lowest capital cost alternatives examined in the PMT. This, and the large ridership increases, result in a capital cost per new weekday transit trip of only $850, which is the lowest cost of any PMT project.

The additional service that would be required would increase operating costs by $1.3 million per year, but generate $1.3 million in new fare revenue. This is one of only a few PMT projects that could operate without a loss.

Bus Lanes Leading to the Sumner Tunnel

A bus lane leading to the Sumner Tunnel could be implemented within the existing roadway with a combination of striping and signage, at a likely cost of less than $100,000. Since the bus lane would reduce travel times, no additional buses would be needed. However, bus times would not be reduced to the extent that fewer vehicles would be needed to operate existing service. The travel time savings would also be too small to result in any significant operating cost savings.

Air Quality Impacts

The provision of better bus distribution in downtown Boston would reduce regional emissions by 0.09 percent, while a Sumner Tunnel bus lane would have no measurable impact on regional emissions (see Table G-44).

Table G-44
Air Quality Impacts of Bus Lanes/Bus Service Improvements

	% Reduction Regional Emissions	Capital Cost/kg of VOC Elim/weekday
Bus Loops in Downtown Boston	0.09%	$79,600
Sumner Tunnel Bus Lane	<0.01%	NA

Better bus distribution in downtown would result in relatively large air quality benefits, because a large proportion of the routes are express routes and would attract long trips. The 0.09 percent decrease in regional emissions that could be achieved if all of the downtown routes were extended would be exceeded among downtown area projects only by the North Station - South Station Rail Link, Circumferential Transit lines, and a Blue Line extension that goes to Riverside via Government Center. The capital cost per kilogram of VOC that would be eliminated each weekday would be $79,600. This would be by far the lowest cost for any project that would make a significant impact.

Conclusions

The reconfiguration of bus service in downtown Boston to provide better service coverage to the Financial District, Downtown Crossing, Government Center, Beacon Hill, and Chinatown would eliminate a transfer or a long walk for many riders and potential riders. The improved convenience that could be provided would attract a large number of new riders—11,880 total trips including 7,220 new transit trips. This would be one of the largest ridership increases that could be achieved by any of the PMT alternatives. The large ridership increase would also translate into a relatively large reduction in regional emissions.

Further, the improved service could be provided at one of the lowest costs of any PMT projects. Including the purchase of new buses, the total capital cost would be $6.1 million. In terms of the number of new riders attracted and the air quality benefits, this cost is very low. The new services would also generate new fare revenue equal to the cost of operation ($1.3 million per year).

The only potential negative to this alternative is the impact on traffic conditions on certain streets, which are not known at this time. Overall, this alternative would remove much more traffic than would be added (the removal of up to 2,850 cars in the AM peak versus the addition of 150 buses). However, localized problems could be caused by the concentration of bus service on certain streets, and subsequent analysis would be needed to determine these impacts. However, if there are severe impacts in a specific area, other alignments could be used that would provide similar benefits.

A Sumner Tunnel bus lane would be relatively easy to implement but would not provide any significant benefits. Further, it may cause problems for traffic exiting from the airport, and would reduce general traffic roadway between the airport and the tolls. If an exclusive lane is instituted at some future date for taxis, trucks, and/or HOVs, it would also provide a benefit to buses. However, the institution on an exclusive lane only for bus purposes does not appear warranted.

Expansion of Existing Parking Facilities

This section summarizes the results of the PMT analysis of expanding existing rapid transit and commuter rail park and ride facilities.

Existing Conditions

Until the recession, access to much of the rapid transit and commuter rail systems was constrained by the lack of available parking. Even with demand down from peak 1989 levels, a large number of stations remain at or beyond capacity. Projected growth will increase demand.

Both the SIP and CA/T Mitigation conditions require the expansion of park and ride facilities: 10,000 new spaces by the end of 1996 and 10,000 spaces by the end of 1999. The addition of new spaces will increase ridership in the short-term by adding supply for existing unmet demand and in the long-term by providing supply for new demand.

PMT Alternatives

A number of different alternatives for additional parking were examined in the PMT. These included:

1. Expansion of existing lots.
2. Construction of new stations along major highways (intercept stations).
3. Construction of park-and-ride lots for existing express bus services.
4. Construction of new lots in conjunction with the implementation of new services.

This section addresses the expansion of existing lots. The construction of intercept stations is addressed in the "Intercept Stations" section, the construction of express bus lots is addressed in the "New/Improved Express Bus Services" section, and the construction of new lots in conjunction with new services is described in the section on each specific project.

The MBTA has identified the lots that it believes could be expanded by the end of 1996, the end of 1999, and thereafter. As shown in Tables G-45, G-46, and G-47, 1,510 spaces could be added at existing lots by 1996, 10,967 by 1999, and an additional 8,678 thereafter.

Table G-45
Expansion of Existing Lots by 1996

Line/Station	Current Lot Size	Proposed Increase	Possible Completion	Capital Cost
Haverhill / Reading Line				
Haverhill	0	300	1993/94	$600,000
Fitchburg Line				
Fitchburg	0	100	1993/94	$200,000
Framingham Line				
Framingham	121	300		$600,000
West Natick	163	300		$4,500,000
Attleboro / Stoughton Line				
Canton Junction	520	310	1993/94	$620,000
Fairmount Line				
Fairmount	33	200		$400,000
Total New by 1996:		1,510		$6,920,000

Table G-46
Expansion of Existing Lots between 1997 and 1999

Line/Station	Current Lot Size	Proposed Increase	Possible Completion	Capital Cost
Orange Line				
Sullivan	217	400		$8,000,000
Malden Center	165	550		$11,000,000
Oak Grove	768	600		$4,800,000
Wellington	1,253	800		$16,000,000
Red Line				
Alewife	2,209	1,000		$20,000,000
Quincy Adams	2,227	1,400		$18,000,000
Blue Line				
Wonderland	1,223	1,000		$2,000,000
Green Line				
Woodland	448	800		$16,000,000
Waban	54	30		$60,000
Add'l RT 1997 - 1999		6,580		$95,860,000
Lowell Line				
Wilmington	0	350		$700,000
Fitchburg Line				
N. Leominster	60	300		$600,000
Franklin Line				
Dedham CC	497	500		$10,000,000
Walpole	210	237		$474,000
Attleboro/Stoughton Line				
South Attleboro	532	300		$2,400,000
Sharon	624	200		$400,000
Route 128	803	2,500		$50,000,000
Add'l CR 1997 - 1999		4,387		$64,574,000
Total Add'l 1997 - 1999		10,967		$160,434,000

Table G-47
Expansion of Existing Lots after 1999

Line/Station	Current Lot Size	Proposed Increase	Possible Completion	Capital Cost
Red Line				
Braintree	1,228	600		$9,000,000
Wollaston	522	300		$600,000
North Quincy	1,203	500		$7,500,000
Blue Line				
Beachmont	404	300		$600,000
Orient Heights	365	190		$380,000
Green Line				
Riverside	0	1,000		$15,000,000
Add'l RT Expansion after 1999		2,890		$33,080,000
Rockport / Ipswich Line				
Rockport	30	60		$120,000
Gloucester	34	156		$312,000
Beverly Depot	200	500		$1,000,000
Salem	340	1,100		$2,200,000
Saugus	0	1,000		$2,000,000
Lowell Line				
North Billerica	333	500		$7,500,000
Fitchburg Line				
Ayer	30	300		$600,000
Kendal Green	60	940		$1,880,000
Framingham Line				
Natick	70	200		$400,000
Wellesley Farms	135	57		$114,000
Auburndale	30	25		$50,000
West Newton	45	100		$200,000
Needham Line				
Needham Heights	16	350		$700,000
Attleboro / Stoughton Line				
Mansfield	845	500		$1,000,000
Add'l CR Expansion after 1999		5,788		$18,076,000
Total Add'l after 1999		8,678		$51,156,000

Ridership Impacts

On a line-by-line basis, there will be more demand than spaces on most lines by 2020, even with the construction of all possible expansions (see Table G-48). On rapid transit, exceptions would be the Red Line and the Blue Line, where fewer spaces would be needed. On commuter rail, demand would exceed supply on all lines except the Attleboro/Stoughton Line (where the largest increases are possible). On most lines, the imbalances would be large.

Table G-48
2020 Parking Demand at Existing Rapid Transit and Commuter Rail Lots

	1988 Spaces	2020 Demand	Potential Spaces in 2020
Rapid Transit			
Red Line	8,679	11,520	12,479
Orange Line	2,598	5,850	4,948
Blue Line	2,092	2,700	3,582
Green Line	2,223	4,500	4,053
Subtotal-Rapid Transit	15,592	24,570	25,062
Commuter Rail			
Rockport/Ipswich	1,372	4,095	4,188
Haverhill/Reading	985	3,510	1,285
Lowell	1,374	4,050	2,224
Fitchburg	800	2,970	2,440
Framingham	860	3,060	1,842
Needham	611	1,980	961
Franklin	1,155	4,250	1,892
Attleboro/Stoughton	2,359	5,220	6,169
Subtotal-Commuter Rail	9,516	29,130	21,001
Total	25,108	53,700	46,063

The total 2020 parking demand represents an increase in ridership of 14,490 new rapid transit trips and 19,080 new commuter rail trips. Of these, 3,690 of the rapid transit trips, and 8,350 of the commuter rail trips represent new transit trips.

Note that the analysis conducted herein was, as mentioned above, conducted on a line-by-line basis, and not a station-by-station basis. These figures indicate that there will be a large demand for additional park and ride facilities, especially if rapid transit and commuter rail services are improved and expanded. However, additional analysis is still required to determine if the potential expansions assumed herein are the most appropriate to serve the projected demand.

Costs and Cost-Effectiveness

The expansion of existing parking facilities would be relatively inexpensive compared to the implementation of new rail services, with total costs, excluding land acquisition, of $128.9

million for rapid transit and $89.6 million for commuter rail (see Table G-49). Costs for individual stations would range from a low of $50,000 to up $50 million for a major expansion of the Route 128 station (capital costs for individual stations are shown in Table 1, 2, and 3). These costs, in terms of the new transit ridership generated would be relatively low for rapid transit and very low for commuter rail. Exclusive of land acquisition costs, the capital cost per new transit rider would be $34,940 for rapid transit and $10,720 for commuter rail (rapid transit is higher because more of the projects involve parking garages instead of surface lots). Even with land acquisition, these costs should remain low.

Table G-49
Cost-Effectiveness of Expanding Existing Rapid Transit and Commuter Rail Lots

	Operating Cost (Annual)	Fare Revenue (Annual)	Parking Revenue (Annual)	Capital Cost[22]	Capital Cost/ New Trip
Rapid Transit	Low	$0.5m	$2.4m	$128.9m	$34,940
Commuter Rail	Low	$2.8m	$2.1m	$89.6m	$10,720

Operating costs would be low, and more than offset by new fare revenue and parking revenues. For all rapid transit stations combined, $2.9 million would be generated in new fare and parking revenue ($0.5 million from fares; $2.4 million from parking fees). For all commuter rail stations combined, $4.9 million would be generated ($2.8 million from fares; $2.1 million from parking fees). Expansion of parking lots would be one of the few projects that could significantly increase ridership while reducing the operating deficit.

Air Quality Impacts

All of the new lots combined would reduce regional emissions by up to 0.18 percent (0.04 percent for rapid transit and 0.14 percent for commuter rail—see Table G-50). This would place park and ride expansion among the more effective projects in the PMT in terms of air quality benefits (only the North Station - South Station Rail Link and Circumferential Transit are higher). The cost of achieving these benefits, in terms of the cost per kilogram of VOC eliminated per weekday, would be moderate for rapid transit, at $4,212,000, and very low for commuter rail at $745,000.

Table G-50
Air Quality Impacts of Expanding Existing Rapid Transit and Commuter Rail Lots

	% Reduction Regional Emissions	Capital Cost/kg of VOC Elim/weekday
Rapid Transit	0.04%	$4,212,000
Commuter Rail	0.14%	$745,000

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[22] Costs do not include land acquisition.

Conclusions

The expansion of existing park and ride facilities on existing rapid transit and commuter rail lines would be one the most cost-effective ways to divert a significant number of automobile users to transit for the majority of their trip. The creation of all of the over 21,000 potential additions would attract 12,040 new transit trips.

The cost of the new lots would be low relative to the number of new trips attracted, although relatively expensive in absolute terms—$128.9 million for rapid transit, and $89.6 million for commuter rail, exclusive of land acquisition costs.

Lastly, the expansion of parking facilities would generate up to $7.8 million per year in new fare and parking fee revenue. Considering that the cost of "operating" park and ride facilities is low, most of this new revenue would represent a reduction in the annual operating deficit.

Intercept Stations along Major Highways

This section summarizes the results of the PMT analysis of constructing intercept stations along major highways to provide better roadway connections to rail lines and express bus services. In general, this would entail the construction of new stations or park and ride facilities at the intersection of rail lines, express bus routes, and major highways. Construction of other express bus parking facilities is considered in the section "New/ Improved Express Bus Services."

Existing Conditions/PMT Alternatives

The Boston region has in place an extensive network of radial rapid transit and commuter rail lines. Beyond the core area, the predominant mode of access to these services is by automobile. Existing stations at the intersection of major highways and rail lines are among the most heavily utilized. Current stations with convenient access from major highways are the following:

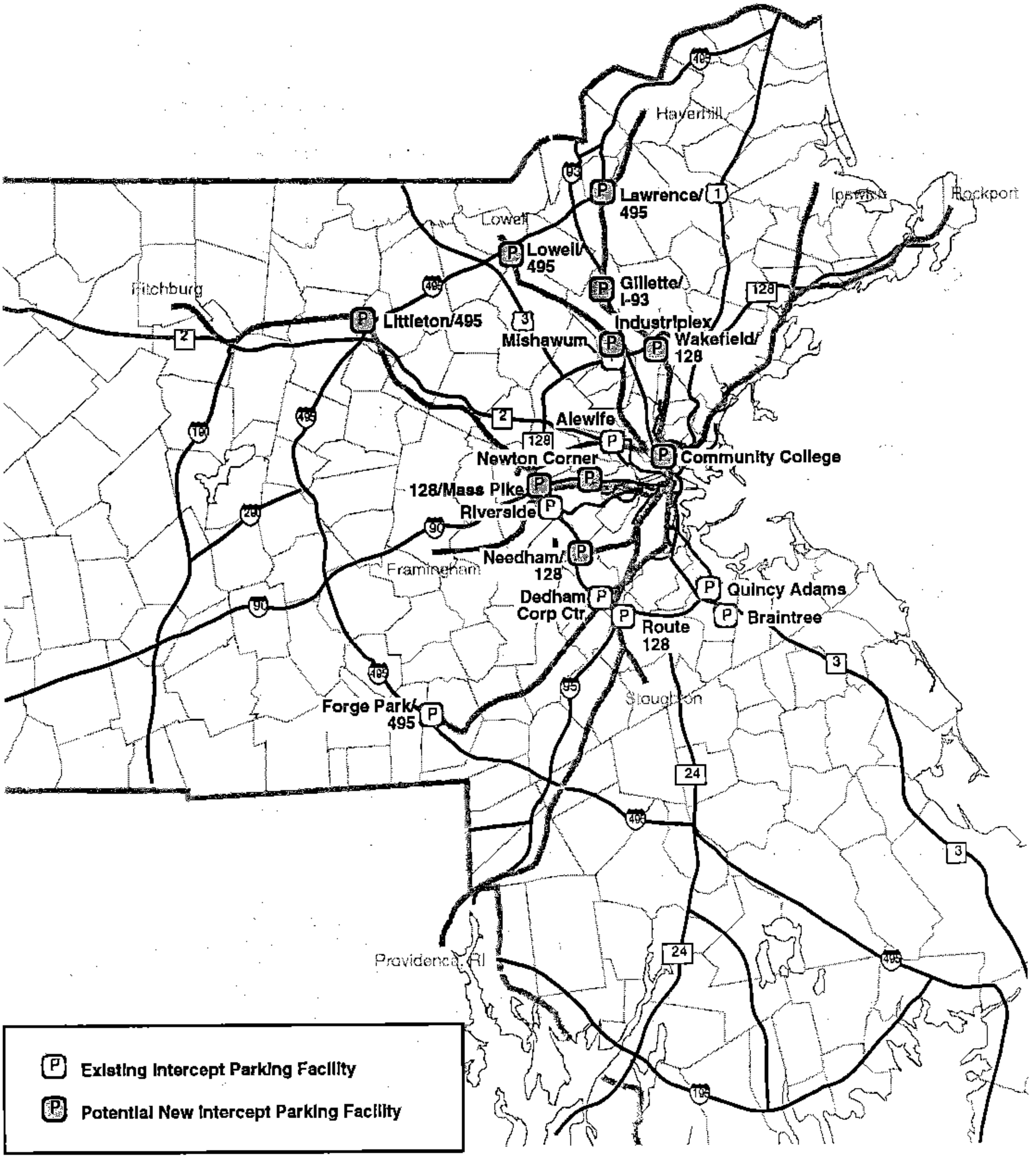
Station	Line	Highway
Alewife	Red Line	Route 2
Riverside	Green Line	Route 128
Quincy Adams	Red Line	Routes 128, I-93, and 3
Braintree	Red Line	Route 3
Dedham Corporate Center	Franklin CR	Route 128
Route 128	Attleboro/Stoughton CR	Route 128
Forge Park/495	Franklin CR	I-495
Mishawum	Lowell CR	Route 128

Most lines do not have stations located adjacent to major highways that also have convenient access and sufficient parking. In some cases, this causes riders to park on local streets instead, generating friction with local residents and businesses. Potential locations for new stations that would improve both access and community relations include (see also Figure G-29):

Station	Line	Highway	Parking Spaces
Lawrence/495	Haverhill/Reading CR	I-495	1,000
Lowell/495	Lowell CR	I-495	500
Littleton/495	Fitchburg CR	I-495	300
Gillette/I-93	Haverhill/Reading CR	I-93	100
Community College	Orange Line	I-93	1,900
Industriplex	Lowell CR	I-93/Route 128	1,000
Wakefield/128	Haverhill/Reading CR	Route 128	300
Route 128/Mass Pike	Framingham CR, Express Bus (300), Green Line	Route 128	1,000
Needham/128	Needham CR	Route 128	800
Newton Corner	Express Bus (301, 302, 304)	I-90	900

It should be noted that specific locations for many of these potential stations have not been determined. As a result, lot sizes are based on projected demand, rather than available space.

Figure G-29
Intercept Parking Locations



Parking fees were assumed to be $2.50 per day for rapid transit, and $1.00 per day for commuter rail and express bus. In estimating demand, it was also assumed that higher levels of service would be operated on most lines than at present. The service levels assumed are the same as those for the "Faster Commuter Rail Service" alternatives.

Ridership Impacts

New park and ride lots located at the intersection of major highways, rail lines, and express bus services would result in large increases in ridership on existing lines. As shown in Table G-51, if all of the stations were constructed, demand would be 6,090 cars per weekday. Assuming an average auto occupancy of 1.17 and two one-way trips per person per weekday, this would translate into a total demand at these stations of 14,310 trips per weekday. Of these, approximately 28 percent, or 3,980, would represent new transit trips. The remainder would generally represent trips made by existing commuter rail riders that would find the new stations more convenient. The new ridership would represent one of the largest diversions from automobiles to transit of all PMT projects, after an inner circumferential LRT line and the North Station - South Station Rail Link.

Table G-51
Ridership Impacts of Intercept Station Construction

Station	Line	Parking Demand	Weekday Transit Trips
Lawrence/495	Haverhill/Reading CR	880	2,070
Lowell/495	Lowell CR	410	990
Littleton/495	Fitchburg CR	230	540
Gillette/I-93	Haverhill/Reading CR	55	130
Community College	Orange Line	1,620	3,800
Industriplex/I-93	Lowell CR	470	1,100
Wakefield/128	Haverhill/Reading CR	190	440
Route 128/Mass Pike	Framingham CR, Green Line, and Express Bus (300)	810	1,900
Needham/128	Needham CR	630	1,480
Newton Corner	Express Bus (301, 302, 304)	800	1,880
Total		6,090	14,310

Note: Parking demand is in terms of the number of cars per weekday.

Some comments with respect to individual stations are as follows:

Lawrence/495

The existing Lawrence station is near downtown Lawrence, approximately one and three-quarter miles north of I-495. The station has 263 parking spaces, but only about 40 riders per day park at the station. Much higher demand for an I-495 station would be attributable to two factors: better highway access and the higher level of service. The demand estimate for 880 spaces assumes that much higher levels of service, express trains, and faster local service would be operated to the Lawrence/495 station.

As described in the "Faster Commuter Rail Service" section, higher service levels, express trains, and faster local service would attract 4,540 additional trips (2,980 new transit trips) to the Haverhill/Reading Line. A large proportion of these trips would use a Lawrence/495 station. The projected demand of 2,070 trips per day would be higher than current ridership at any existing northside station, and among the highest ridership stations systemwide.

Lowell/495

This station would be located at the Woburn Street exit off of I-495 in Lowell near the Tewksbury and Billerica borders. The most likely location for this station would be the site of an abandoned parking lot owned by Raytheon that is adjacent to the railroad tracks. Raytheon had previously been unwilling to sell this parcel; however, Raytheon has recently instituted cutbacks at this facility and this situation may have changed.

North Billerica station is currently the most convenient Lowell Line station to I-495. It is on Woburn Street approximately three miles south of I-495, and is currently utilized by a large number of riders that access the station via I-495. North Billerica has 333 parking spaces. Except in summer, the lots are near or over capacity. Expansion of parking at this station is constrained by opposition from the town of Billerica.

With a Lowell/495 station, all commuter rail passengers that now access North Billerica station via I-495 could be expected to shift to the new station. This analysis was not detailed enough to determine the exact number, but the shift from North Billerica likely represents a large proportion of the demand for the new station. Ridership at a Lowell/495 station would compare favorably with current ridership at existing northside stations.

Littleton/495

The current Littleton/495 station, is within sight of both Route 2 and I-495, but cannot be easily accessed from either. Further, it has only 15 parking spaces; approximately 55 people per day park at or near the station.

A Littleton/495 station with better access would serve approximately 540 auto access trips per weekday. This would be low compared to other stations on major highways, but significantly higher than the 160 trips currently made to and from the existing Littleton/495 station. The lower than average projected ridership is likely attributable to relatively long travel times on the Fitchburg Line.

Gillette/I-93

This station would be located on the Haverhill Line off of I-93 near the Gillette plant in Andover. Demand at this station would be the lowest of all the new stations examined, at only 130 trips per weekday.

Community College

A Community College station with access from I-93 could attract up to 3,800 additional trips per weekday to the Orange Line. Parking demand would be for 1,620 spaces. The cost estimates included herein assume a surface lot, at $3.8 million. However, the size might require a structure in which case costs would be significantly higher.

High demand for this facility reflects parking shortages at other stations on the northern end of the Orange Line, plus improved connections. Currently, the most convenient station to I-93 is Sullivan Square. However, MBTA parking there is limited (only 217 spaces), and available private parking is more expensive (typically $4.00 per weekday). The next most convenient station is Wellington, which lacks adequate egress from the station to I-93. With parking at Community College, many of the existing trips now made through Wellington and Sullivan would shift to Community College. It is likely that users of a

Community College/I-93 connection would be equally well served by expanded parking at Sullivan Square, but this was not examined in the PMT.

Industriplex/I-93

This station, which would be located near the intersection of I-93 and Route 128 with direct connections from I-93 would replace the existing Mishawum Station on the Lowell Line. Total parking demand would be for 470 spaces per weekday. This would compare to approximately 290 cars per weekday parked at Mishawum. The increase would be attributable to a number of factors:

(1) Better Access. Access to and from Mishawum Station from I-93 and Route 128 is inadequate. Access to an Industriplex station would be better from I-93, and possibly also better from Route 128.

(2) Assumed improvements in commuter rail service, including express trains.

(3) Growth in total work trips to Boston from this area between now and 2020.

Total ridership at the Industriplex/I-93 station would be relatively high compared to current ridership at existing stations.

Wakefield/128

The Haverhill/Reading Line currently has stations north and south of Route 128 (Reading and Wakefield stations). Each is nearly one mile from Route 128, and parking demand at both typically exceeds lot capacity. A new station at the intersection of Route 128 and North Avenue could provide additional parking supply and better access to and from Route 128. Parking demand would be for approximately 190 spaces per weekday. This demand is relatively low compared to similar stations on other lines. It is also significantly less than the 600 cars that now park at the Reading and Wakefield stations. This indicates that much of the parking at those stations serves riders from relatively close residential areas, and that there would not be a large number of diversions to the new station.

Route 128/Mass Pike

A new station near the intersection of Route 128 and the Mass. Pike would be served by the Framingham commuter rail line, the Riverside branch of the Green Line, and express buses. This station would attract a demand for 810 spaces. However, a prior study[23] indicated that most of this demand would represent diversion from other transit services.

Needham/128

A new commuter rail station on the Needham Line at Route 128 would attract a demand for 630 spaces. Due to lack of available land in this area, a Needham/128 station would likely need to be built as a structure over Route 128, with access possible only in motor vehicles. Total ridership would be up to 1,480 trips per weekday. This would be high relative to current ridership at existing stations.

Newton Corner

Newton Corner is served by three MBTA express routes: 301, 302, and 304. The level of service on these routes is very high, and the routes are very well utilized. No MBTA parking is provided; those who access the routes by automobile park on streets around

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[23] See Quackenbush, K. H. and F. Ngai (1991), "Route 128/Massachusetts Turnpike Park-and-Ride Facility," CTPS Memorandum.

Newton Corner. The lack of parking limits ridership, and the on-street parking by existing riders has created opposition to the express bus services from area residents.

Because of space constraints, it was assumed that a Newton Corner parking facility would be constructed on air rights over the Mass Pike. The parking facility would also include bus terminal and passenger facilities. Such a facility would attract a demand for 800 spaces, which would be higher than for most commuter rail stations, as well as for many Green Line stations.

Costs and Cost-Effectiveness

New stations with park and ride facilities on existing lines would be relatively inexpensive relative to the implementation of new rail services, with a total cost, excluding land acquisition of $60.2 million. Costs for individual stations would range from a low of $2.7 million up to $16.0 million for a garage over the Mass Pike at Newton Corner (see Table G-52). These costs, in terms of the new transit ridership generated would be low. Exclusive of land acquisition costs, the capital cost per new transit rider would be only $15,100 (see Table G-53). Even if land acquisition doubled the cost to over $30,000, this would still be among the lowest cost per new transit rider among all PMT projects.

Table G-52
Capital Costs for Intercept Stations

Station	Line	Capital Costs
Lawrence/495	Haverhill/Reading CR	$4.5m
Lowell/495	Lowell CR	$3.5m
Littleton/495	Fitchburg CR	$3.1m
Gillette/I-93	Haverhill/Reading CR	$2.7m
Community College	Orange Line	$3.8m
Industriplex/I-93	Lowell CR	$4.5m
Wakefield/128	Haverhill/Reading CR	$3.1m
Route 128/Mass Pike	Framingham CR, Green Line, and Express Bus (300)	$4.5m
Needham/128	Needham CR	$14.5m
Newton Corner	Express Bus (301, 302, 304)	$16.0m
Total		$60.2m

Note: Capital costs do not include land acquistion or highway connections, but do include the cost of a new station, where applicable.

Operating costs would be low, and more than offset by new fare revenue and parking revenues. For all stations combined, $2.8 million would be generated in new fare and parking revenue ($2.2 million from fares; $0.6 million from parking fees). Construction of new lots would be one of the few projects that could significantly increase ridership while reducing the operating deficit.

Table G-53
Cost-Effectiveness of Intercept Stations

	Operating Cost (Annual)	Fare Revenue (Annual)	Parking Revenue (Annual)	Capital Cost[24]	Capital Cost/ New Trip
Intercept Stations	Low	$2.2m	$0.6m	$60.2m	$15,100

Air Quality Impacts

All of the new lots combined would reduce regional emissions by up to 0.08 percent (see Table G-54). This would place intercept park and ride lots as among the more effective projects in the PMT in terms of air quality benefits. The cost of achieving these benefits, in terms of the cost per kilogram of VOC eliminated per weekday, would be relatively low, at $911,000.

Table G-54
Air Quality Impacts of Intercept Stations

	% Reduction Regional Emissions	Capital Cost/kg of VOC Elim/weekday
Intercept Stations	0.08%	$867,500

Conclusions

The construction of new park and ride facilities on existing rail and express bus services would be one the most cost-effective ways to divert a significant number of automobile users to transit for the majority of their trip. Were all 12 new stations examined by the PMT to be constructed, they would be utilized by 7,160 people per weekday. These people would make 14,310 total trips per day, including 3,980 new transit trips.

The cost of the new lots would be low relative to the number of new trips attracted—$60.2 million in total costs, or $15,100 per new transit trip—excluding land acquisition costs. Even with allowances for high land costs, the capital cost per new trip would be very low.

Lastly, new parking facilities would generate up to $2.8 million per year in new fare and parking fee revenue. Considering that the cost of "operating" park and ride facilities is low, most of this new revenue would represent a reduction in the annual operating deficit.

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[24] Costs do not include land acquisition.

New Commuter Rail - Rapid Transit Connections

At present, seven MBTA commuter rail stations are also served by rapid transit lines. These are North Station, Malden Center, and Porter Square on the northside system, and South Station, Back Bay, Ruggles, and Forest Hills on the southside system. During the PMT planning process, additional transfer stations were suggested for a number of other locations where commuter rail lines pass close to rapid transit lines. The purpose of such new transfer stations would be to improve connections and expand travel possibilities. Six new commuter rail-rapid transit connections were analyzed in detail. These were between:

1. the Fitchburg Line and the Red Line at Alewife.
2. the Rockport/Ipswich Line and the Blue Line near Wonderland.
3. the Framingham Line and the Green Line near Riverside
4. the Fairmount Line and the Red Line near Mattapan
5. the Old Colony Lines and the Red Line at JFK/UMass
6. more southside commuter rail trains and the Orange Line at Ruggles Station

PMT Alternatives/Existing Services

1. Alewife Connection (Fitchburg CR and Red Line)

The Fitchburg Line is currently the longest of the MBTA's commuter rail routes. It runs 49.6 miles from the city of Fitchburg to North Station in Boston and serves 16 other stations. Present weekday service includes ten round trips over the full route and six round trips between South Acton and Boston (25.3 miles).

The PMT analysis examined a new transfer connection between the Fitchburg Line and the Red Line at Alewife Station (see Figure G-30). This would require a diversion of the Fitchburg Line over abandoned rail rights of way owned by the MBTA. The new segment would be about one mile long, and would lengthen the Fitchburg Line by 0.25 miles. It was assumed that all Fitchburg trains would stop at Alewife Station.

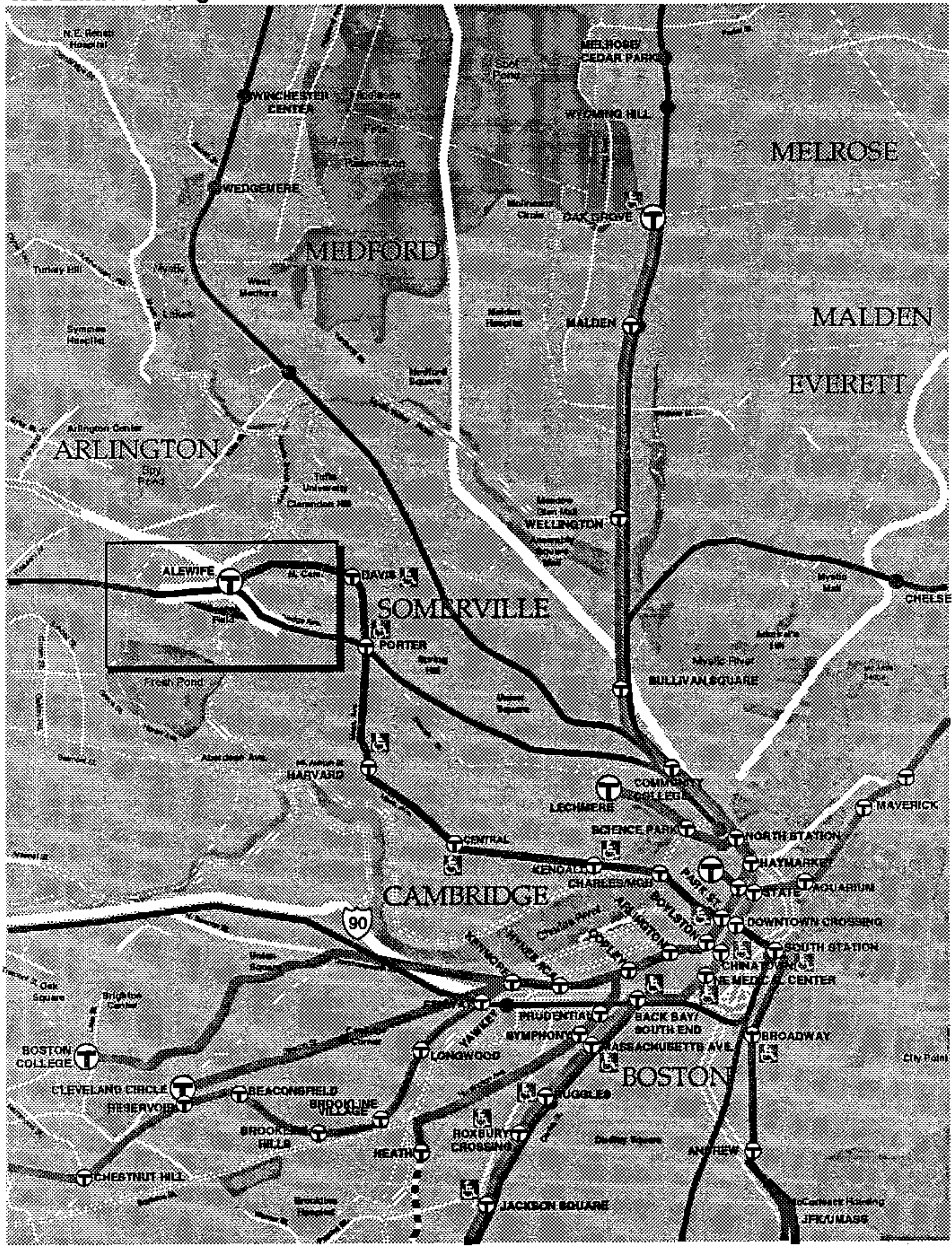
The Fitchburg Line now connects directly with the Red Line at Porter Square station, which is 1.5 miles from Alewife. However, the great length of escalators at Porter makes this a relatively time-consuming transfer. At Alewife, there would be much less difference in elevation between the commuter rail and Red Line tracks, but the locations of the railroad right of way and the present parking garage would force a greater horizontal separation of the platforms. Therefore, it is unclear whether passengers would find an Alewife transfer more attractive than the Porter transfer.

2. Wonderland Connection (Rockport/Ipswich CR and Blue Line)

The Rockport/Ipswich commuter rail line consists of two routes sharing a common alignment from Boston to Beverly Junction, then dividing into separate branches to Rockport and Ipswich. Including the endpoints, 17 stations are served. Present weekday service includes 12 round trips from Boston to Rockport, 11 from Boston to Ipswich, one from Boston to Beverly, and one from Beverly to Ipswich with connections to and from Boston.

The Rockport/Ipswich Line currently has connections to the Orange and Green lines at North Station, but no connections to the Red or Blue lines. The shared alignment passes near the

Figure G-30
Red Line/Fitchburg Commuter Rail Line Connection at Alewife



Blue Line Wonderland terminal. A transfer connection could be created by extending the Blue Line 0.36 miles to a new station on the Rockport/Ipswich Line (see Figure G-31). This would provide a faster service alternative to downtown Boston, as well as connections to Logan Airport. All Rockport/Ipswich Line and Blue Line trains would stop at the transfer station.

3. Riverside Connection (Framingham CR and Green Line)

The Framingham commuter rail line currently runs 21.4 miles from the town of Framingham to South Station in Boston, serving eight other suburban stations and Back Bay Station in Boston. Extension of the line beyond Framingham to Worcester, 44 miles from Boston, is also planned. Weekday commuter service on the Framingham Line currently includes 15 outbound and 16 inbound trains. All trips run through between Framingham and Boston. There are five inbound AM peak trains, at intervals of 30 to 45 minutes and four outbound PM peak trips at intervals of 30 to 35 minutes.

The Framingham Line now has direct transfer connections with the Red Line at South Station and with the Orange Line at Back Bay. Copley Station on the Green Line is about 1,000 feet from Back Bay. The Framingham Line also passes near Riverside Station at the end of the Green Line D Branch, but has no stop there.

The PMT analysis examined a new transfer connection between the Framingham Line and the D Line west of the present Riverside Station (see Figure G-32). The D Line would be extended 0.2 miles over an abandoned rail right of way owned by the MBTA, to a point on the Framingham Line between Auburndale and Wellesley Farms. Platforms and other station facilities for both lines would be built there. This transfer station would be at the site of the Riverside commuter rail station, abandoned in 1977. No usable facilities remain there. For the analysis, it was assumed that all Framingham Line and D Line trains would stop at the transfer station. D Line trains would also continue to serve the present Riverside Station. (Platform locations at the present Riverside Station after completion of a modernization project now underway will be compatible with an extension to a Framingham Line transfer station.)

4. Mattapan Connection (Fairmount CR and Red Line)

The Fairmount Line (the MBTA's shortest commuter rail route) runs 9.1 miles between Readville and South Station. Including the endpoints, it serves five stations, all within the City of Boston. Service is operated weekdays only, on 30-minute peak and hourly off-peak headways. There are 21 round trips between Readville and South Station. (Several trains from other lines are also routed over the Fairmount Line, but only two inbound Franklin Line trains make local stops north of Readville.)

The Fairmount Line passes close to the Mattapan terminal of the Mattapan High Speed Trolley Line, but has no stop there. A transfer station would be built only if the High Speed Line were replaced by an extension of the Red Line from Ashmont to Mattapan. (Such an extension is examined as a separate PMT project.) The transfer station would require a further extension of the Red Line one-quarter mile beyond the current Mattapan Station to a site on the Fairmount Line where platforms for both lines would be built (see Figure G-33). Existing land use would require the extension to be in a subway. For the analysis, it was assumed that all Ashmont Branch Red Line trains and all Fairmount Line trains would serve the transfer station.

Figure G-31
Blue Line / Rockport/Ipswich Commuter Rail Connection near Wonderland

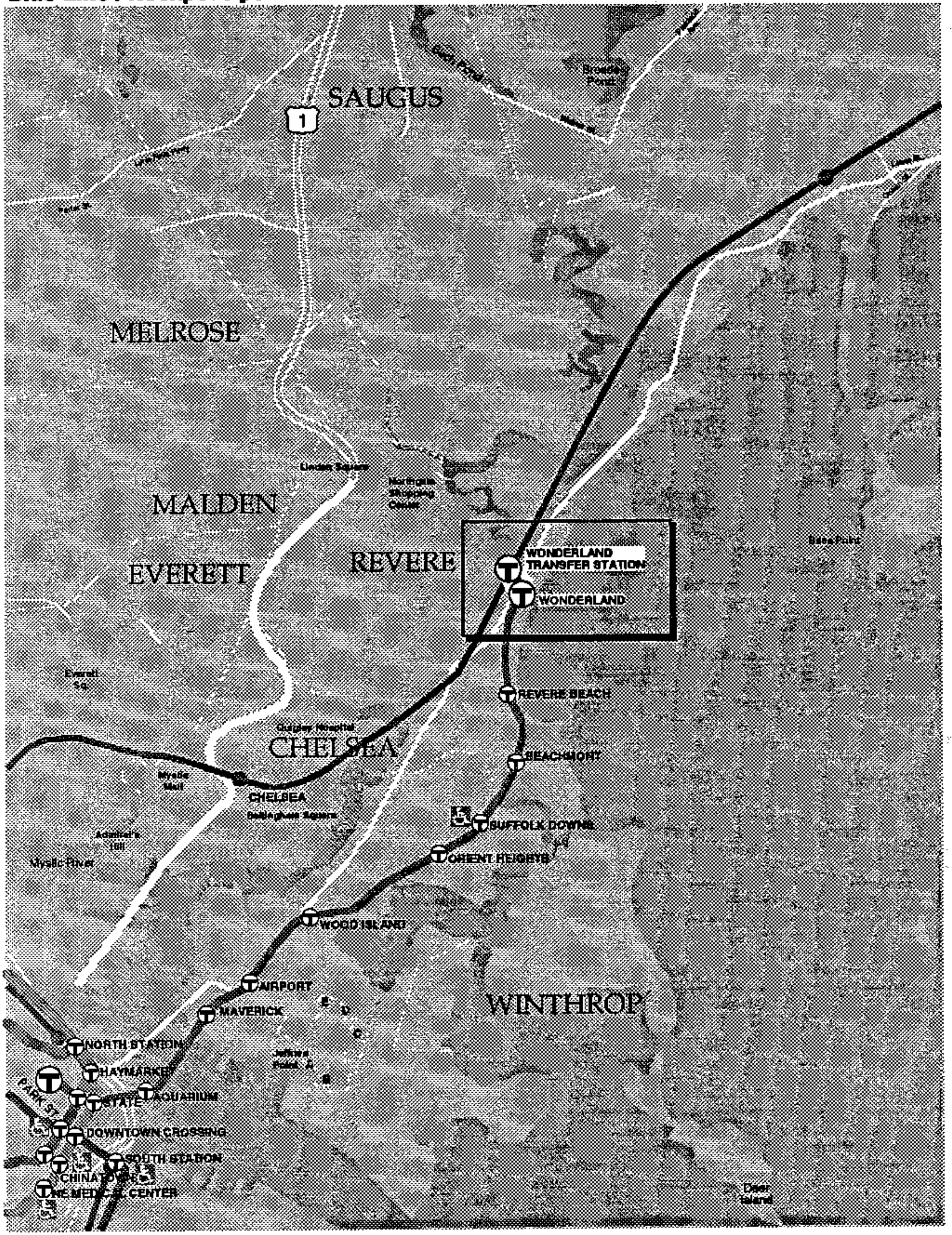


Figure G-32
Green Line / Framingham Commuter Rail Connection near Riverside

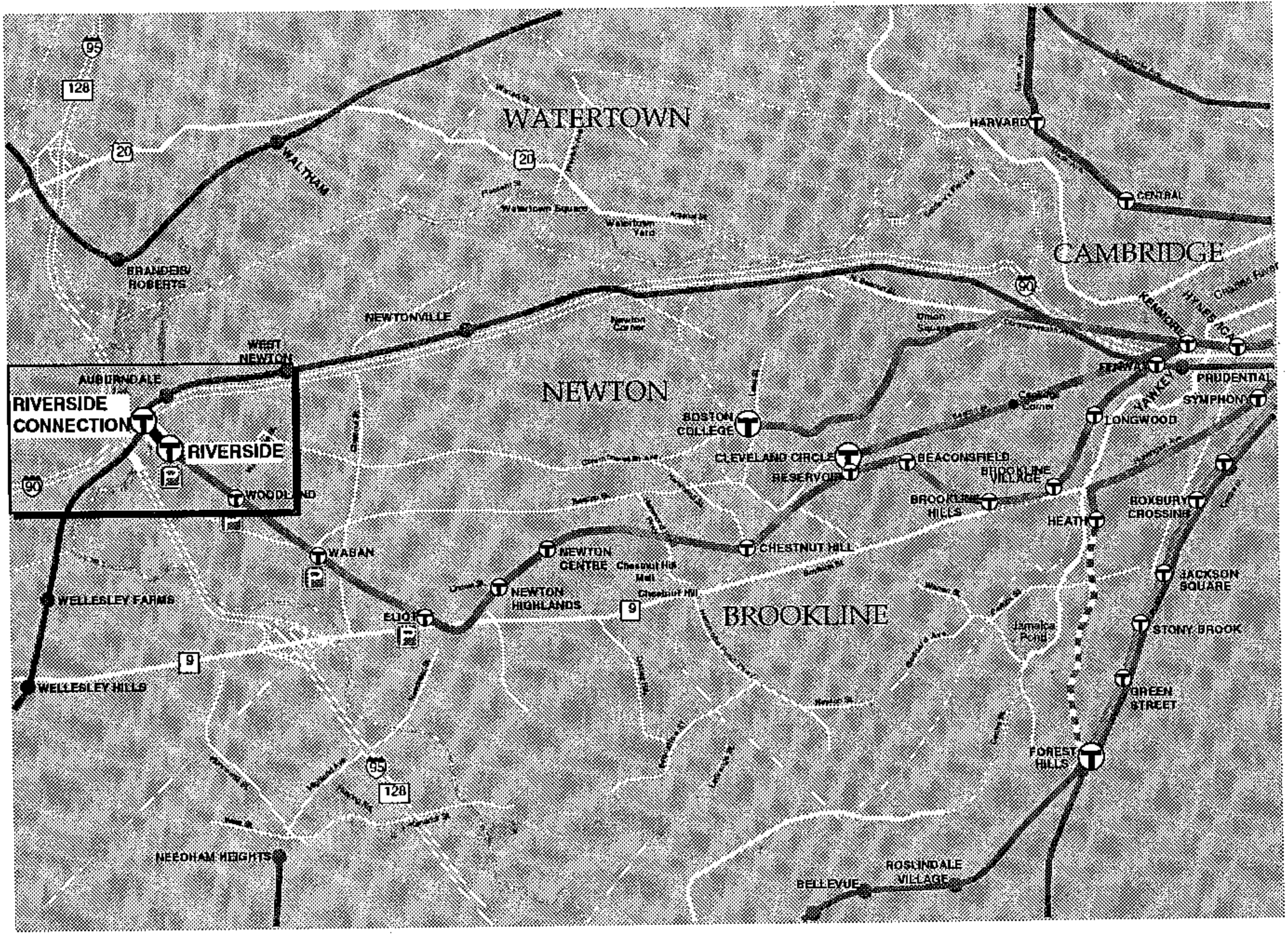
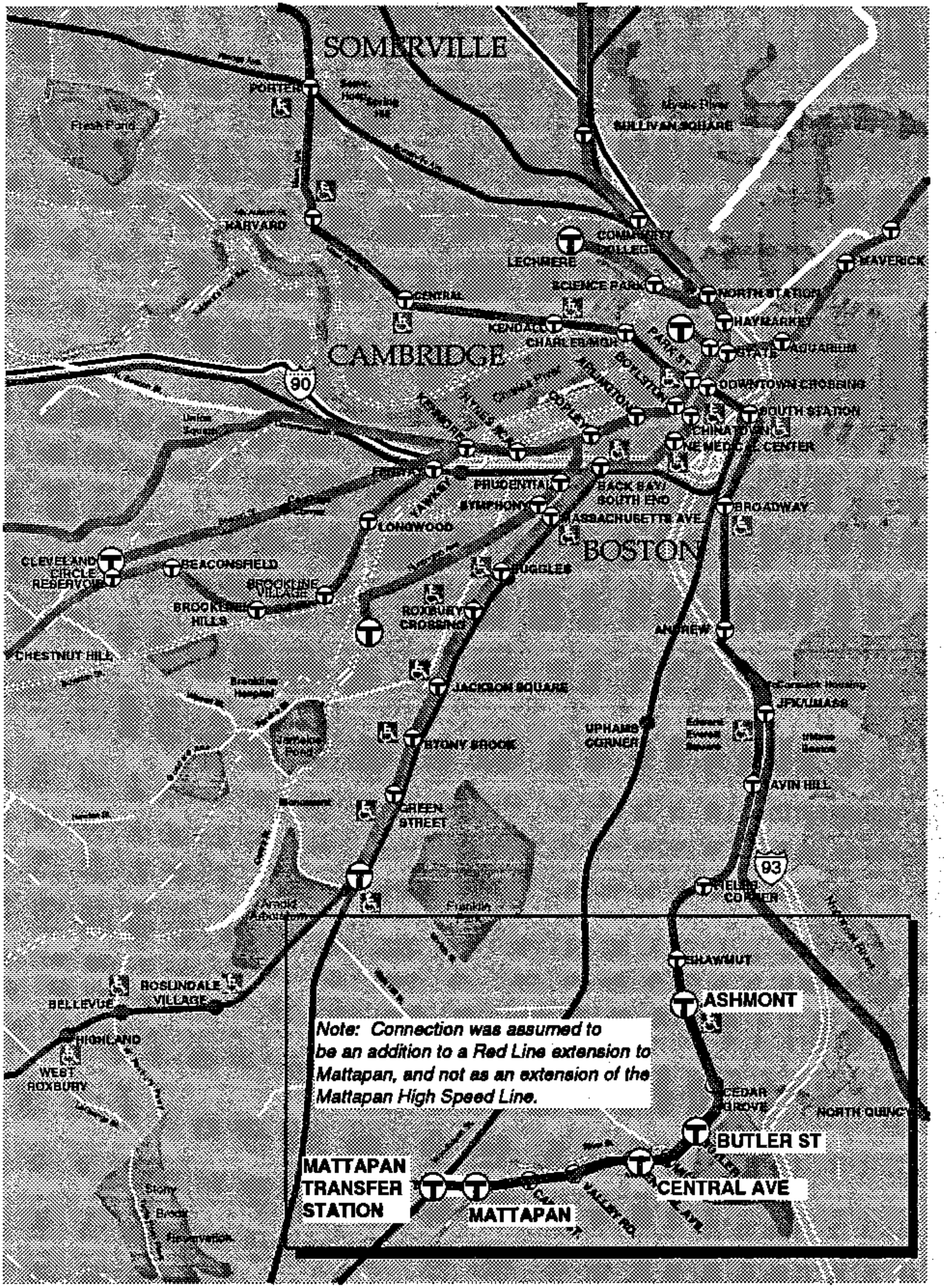


Figure G-33

Red Line/Fairmount Commuter Rail Line Connection at Mattapan



Note: Connection was assumed to be an addition to a Red Line extension to Mattapan, and not as an extension of the Mattapan High Speed Line.

5. JFK/UMass Connection (Old Colony CR and Red Line)

A project currently underway will restore commuter rail service to Boston from the South Shore via former Old Colony Railroad routes from Middleborough and Plymouth. Restoration of service on a third route from the Greenbush section of Scituate is still under study. The Middleborough and Plymouth routes will run in the same right-of-way as the Red Line between Braintree station and Columbia Junction, north of JFK/UMass station. The Greenbush Line would join the others between Braintree and Quincy Adams stations.

The PMT examined the addition of a station for the Old Colony commuter rail lines next to the JFK/UMass Red Line station. This station could be used for transfers to the Red Line and for access to destinations in the area. The latter include UMass/Boston, the John F. Kennedy Library, and the State Archives building, all of which are about one mile from the station and are served by shuttle bus connections. All Old Colony trains would stop at the transfer station.

6. Ruggles Connection (Southside CR and Orange Line)

The Attleboro/Stoughton, Franklin, and Needham commuter rail lines all run in the same right of way as the Orange Line between Forest Hills Station and a point east of Back Bay Station, where the Orange Line enters a subway. At Back Bay, passengers can transfer to the Orange Line from all three of these commuter rail lines. At Forest Hills, transfers are only possible between the Orange Line and the Needham Line. Most Needham and Franklin Line trains now stop at Ruggles Station on the Orange Line. but for reasons detailed below, most inbound peak Attleboro/Stoughton trains omit the Ruggles stop.

Ruggles Station has three railroad tracks and two Orange Line tracks. The Orange Line tracks are furthest west, and use an island platform. From west to east, the railroad tracks are numbered 3, 1, and 2. Tracks 1 and 3 share an island platform. Track 2 has no platform. The three tracks are shared by trains on the Needham Line and by most trains on the Attleboro/Stoughton and Franklin Lines. They are also used by Amtrak Northeast Corridor trains to New York and Washington, D.C.

Track 2 is usually used only by inbound trains. Tracks 1 and 3 are used by trains in both directions. Current schedules require the use of all three tracks during peak hours, and future schedules will have even more trains. With the existing platform layout, trains running on Track 2 cannot serve Ruggles.

At present, all inbound AM peak and outbound PM peak trains on the Needham and Franklin Lines stop at Ruggles (except for two inbound Franklin trains that run via the Fairmount Line). On the Attleboro/Stoughton Line, all outbound PM peak trains except for one Providence trip stop at Ruggles. In the AM peak, however, only one of the four Stoughton trains, one of the two South Attleboro trains, and one of the four Providence trains, are able to stop at Ruggles. Furthermore, two of these trips stop earlier or later than is convenient for most commuters. Passengers from the other trains must ride to Back Bay and make reverse transfers to the Orange Line to get to Ruggles. .

The PMT analysis examined construction of a platform for Track 2 at Ruggles Station. This would enable trains on any track to stop at Ruggles. Most commuter rail passengers now alighting at Ruggles leave the station rather than transferring to the Orange Line there. A platform on Track 2 could also be expected to be used by more exiting than transferring riders.

Ridership Impacts

The rapid transit/commuter rail connections described above would make service more convenient for a number of existing riders, but most of them would attract relatively few new transit riders (see Table G-55). The new connections would also increase travel times for downtown Boston commuter rail riders that would not use the connections. Except for the Wonderland connection, the number of total trips attracted by the connections would be low relative to other extensions and/or ridership at existing rapid transit stations.

Table G-55
Ridership Impacts of Rapid Transit/Commuter Rail Connections

	Total Trips	New Transit Trips
Alewife Connection	1,020	348
Wonderland Connection	7,200	1,080
Riverside Connection	876	876
Mattapan Connection	1,680	189
JFK/UMass Connection	952	266
Ruggles Connection	984	328

Alewife Connection

In 2020, the Alewife connection would be used for 1,020 transfers per weekday (510 in each direction) between the Fitchburg commuter rail line and the Red Line. Of these, 350 would be diversions from automobile trips. The other 670 transfers would be made via the now-existing Porter Square connection if an Alewife connection were not provided. With an Alewife connection available, transfers at Porter would be reduced by 27 percent from the base case. The majority of the diversions (73 percent) would be passengers destined for Davis Square. These passengers would have to double back if transferring at Porter.

Fitchburg Line passengers would be more likely to get seats on inbound Red Line trains at Alewife than at Porter. In 1989 counts, Red Line trains usually had empty seats leaving Alewife in the AM peak, but often left Porter with standees. For outbound trips, however, transfer passengers would still face the possibility of standing as far as Porter. Also passengers transferring to the Fitchburg Line outbound would have fewer choices of seats at Alewife than at Porter.

The demand forecasts do not include non-transfer ridership at the Alewife transfer station. Because there is already a Red Line station at this location, addition of a commuter rail station would not generate any new non-transfer ridership for the Red Line, but some new commuter rail trips to and from the station vicinity could be generated. Based on observations at comparable stations in the present system, an Alewife commuter rail station would serve less than 400 non-transfer boardings and alightings per day.

Wonderland Connection

A Wonderland connection between the Rockport/Ipswich Line and the Blue Line would serve the most riders (7,200 total trips per weekday) of all the commuter rail-rapid transit connections examined. It would also serve more riders than six of the twelve existing Blue Line stations currently serve. The connection station ridership would include 1,080 new transit trips.

A Wonderland connection would be used mainly by commuter rail passengers destined for points near downtown Boston Blue Line stations (Bowdoin, Government Center, State, or Aquarium). Most such passengers now either walk from North Station or transfer there to the Green or Orange Lines. Government Center Station is served directly by the Green Line, and State is served directly by the Orange Line, but there is no direct transit service to either Bowdoin or Aquarium from North Station. The demand forecasts indicate that about 70 percent of the passengers using the Wonderland connection would be destined for Bowdoin or Aquarium. Another 20 percent would be destined for Government Center or State, but would find the Wonderland transfer more convenient than the existing options. The remainder would be destined for Blue Line stations in Revere or East Boston. Only 120 weekday trips to or from Logan Airport would be made via the Wonderland connection.

Riverside Connection

A new transfer station near Riverside would serve about 875 riders per weekday in 2020. All would be new transit trips. This is lower than present ridership at any D Line station.

The Riverside transfer would be of benefit mostly to passengers traveling between points west of Riverside on the Framingham Line and points along the D Line west of Copley Station. The demand forecasts indicate that of the inbound transfers at Riverside, 63 percent would be destined to stations from Brookline Village through Kenmore, 14 percent to stations west of Brookline Village, and 22 percent to Hynes/ICA or Copley.

For riders traveling to most parts of downtown Boston from stations on the Framingham Line, transferring to the Green Line at Riverside would not save any time, but could reduce access distance. The commuter rail running time from the Riverside transfer station to South Station would be 25 minutes. The Green Line running time from Riverside transfer to Park Street in peak hours would be at least 35 minutes. A similar time differential would apply for trips to Copley on the Green Line versus Back Bay on the Framingham Line. Back Bay is within a five-minute walk of Copley, and South Station is within ten minutes of Park Street by walking or by Red Line. Therefore, a commuter rail rider going to any destination east of Hynes/ICA could get there faster by walking directly from South Station or Copley or by transferring to rapid transit at one of these stations than by transferring at Riverside.

The PMT demand estimate for a Riverside transfer station did not include non-transfer passengers, but the potential for these is very limited. The proposed site is bounded to the west and south by the Charles River and MDC park land. Residential streets east of the site are on top of a steep bluff with no practical means of access to the proposed station. Most houses to the north are at least a quarter mile away, and the location of the Mass. Pike would force even longer access paths to the proposed station. There is no land near the site suitable either for commuter parking or for large-scale commercial development that would attract riders.

Mattapan Connection

The year 2020 demand forecasts indicate that a new station connecting the Red Line and the Fairmount Line near Mattapan would serve 1,680 commuter rail trips per weekday (840 inbound boardings), but only 190 new transit trips. Most of the 1,490 other Fairmount Line riders at this station would be diverted from Mattapan Station on the Red Line extension. There would also be some shifting of Red Line boardings and alightings from Mattapan Station to the transfer station, but the demand model did not produce a specific number for such diversions.

Few, if any riders would transfer between the Fairmount Line and the Red Line. Inbound transfer riders would have to board the Fairmount Line at either Readville or Fairmount, which would be respectively 2.8 and 1.4 miles from the transfer station. Excluding transfer time, the travel time from the transfer station to South Station would be about 22 minutes by Red Line compared to 16 minutes on the Fairmount Line. Therefore, the Mattapan transfer would only save time for Readville or Fairmount passengers with destinations on the Red Line south of Broadway Station. (Broadway itself could be reached fastest by transferring at South Station.)

It would be possible to use the extended Red Line as a feeder to the Fairmount Line, but the only Red Line Station from which this could provide any travel time savings would be Mattapan. Even from there, greater Red Line frequency would prove more attractive to most riders than shorter line-haul times of a Red Line-Fairmount Line combination.

The ridership figures above presume that with or without a Fairmount Line transfer station, the present Mattapan High Speed Line would be replaced by a Red Line extension to Mattapan. Such an extension alone would carry 4,718 weekday trips, including 1,260 new transit trips.[25] The attractiveness of commuter rail service from the Mattapan area should be even greater in comparison with the present combination of the High Speed Line and the Red Line than with through Red Line service from Mattapan to Boston.

Ridership experience at the existing stations on the Fairmount commuter rail line suggests that the demand predicted for a Mattapan Station may be too high. Morton Street Station, 0.9 miles north of Mattapan, currently serves only about 220 inbound riders per day, and Fairmount Station, 1.6 mile south, serves about 280. No ridership growth on the Fairmount Line between 1988 and 2020 is predicted if no stations are added.

JFK/UMass Connection

The 2010 demand forecasts indicate that a JFK/UMass commuter rail station would serve 1,360 trips per day, of which 380 would be new transit trips.[26] Most of the ridership would consist of non-transfer commuter rail trips to and from locations such as UMass/Boston and the JFK Library. The number of riders transferring between commuter rail and the Red Line at JFK/UMass would be too small to predict, given the limits on the precision of the demand model.

Most of the 980 transit trips diverted to a JFK/UMass commuter rail station would otherwise be made by transferring from commuter rail to the Red Line at Braintree Station. The demand forecasts assume that Middleborough commuter rail trains would stop at the

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[25] For more information, see "Red Line Extension to Mattapan" section.

[26] Old Colony ridership estimates were not updated to 2020 as part of this project. Therefore, all numbers are based on 2010 forecasts.

Braintree commuter rail station, but that Plymouth and Greenbush trains would not stop at any Red Line stations south of JFK/UMass. Plymouth trains will pass through the Braintree Station, and could stop there subject to scheduling constraints. Such service was not modeled, but would probably attract a large share of the 380 new transit trips predicted for JFK/UMass. (Track layout would not permit Greenbush trains to serve Braintree Station.)

A JFK/UMass commuter rail station would be most similar to Ruggles Station on the Needham, Attleboro/Stoughton, and Franklin Lines except that destinations served by Ruggles are within walking distance. In 1989, final commuter rail destinations at Ruggles were equal to three to four percent of combined ridership on the routes that stopped there. Total Old Colony Lines ridership is projected to be 23,240 per day (11,620 each way) by 2010. If 3.5 percent were destined for JFK/UMass this would generate 410 inbound transfers, compared to the 680 predicted by the demand model.

In 1989 counts, 2.6 percent of inbound South Shore Red Line passengers that rode further than North Quincy alighted at JFK/UMass and left the station. This totaled 240 riders in the AM peak, and 440 all day. At the time of these counts, the JFK/UMass platform on the South Shore Branch had been open for only a few months, and may not have developed its full potential. South Shore riders destined for JFK/UMass previously had to ride to Andrew Station and double back. For comparison, 5.3 percent of inbound Ashmont Branch passengers that rode further than Savin Hill alighted at JFK/UMass and left the station. With destination distributions similar to those of Red Line passengers, the Old Colony Lines would have 300 to 600 inbound riders a day using JFK/UMass as a final alighting station.

All Old Colony branches will connect with the Red Line at South Station. Inbound, JFK/UMass Station is before the peak load point on the Red Line, but South Station is after it. Therefore, the number of Old Colony Lines passengers that would find JFK/UMass preferable to South Station as a Red Line transfer point would be small.

Of the passengers currently boarding inbound Red Line trains at stations in Quincy and Braintree in the AM peak, about three percent alight at Broadway or Andrew, and about 0.5 percent make reverse transfers at JFK/UMass to reach stations further south on the Ashmont Branch. If a similar proportion of inbound Old Colony Lines passengers were destined for these stations, this would generate 410 transfer trips in each direction not accounted for in the demand forecasts. In general, however, commuter rail ridership is more heavily oriented than rapid transit ridership to destinations in downtown Boston. In addition, because commuter rail riders would have to transfer to reach Andrew or Broadway compared to direct service for Red Line passengers, the demand potential for these stations would be smaller.

Ruggles Connection

The PMT demand forecasts indicate that a commuter rail platform on Track 2 at Ruggles Station would attract 985 new riders, including 330 new transit trips. Most of the ridership would represent trips to and from the Ruggles area and bus transfers. Relatively few (approximately 120) would be transfers to and from the Orange Line.

Few Orange Line transfers would be made because Ruggles would be a less convenient transfer location than Back Bay for most riders. Inbound, Orange Line trains are less crowded at Ruggles than at Back Bay at most times, but during AM peak hours seats are not available at either station. Therefore, passengers transferring at Ruggles have to stand longer. Platforms are more sheltered at Back Bay than at Ruggles. Passengers exiting commuter rail platforms at Back Bay have a choice of stairs, escalators, or elevators. The Ruggles commuter rail platform has only stairs and an elevator.

Costs and Cost-Effectiveness

As shown in Table G-56, the construction costs of new transfer stations would range from $1.6 million (at JFK/UMass and Ruggles, where most facilities now exist, to $9.3 million near Wonderland.

Table G-56
Cost-Effectiveness of New Rapid Transit/Commuter Rail Connections

	Operating Cost (Annual)	Fare Revenue (Annual)	Capital Cost[27]	Capital Cost/ New Trip
Alewife	Low	$80,000	$7.6m	$21,700
Wonderland	$461,000	$247,000	$9.3m	$8,630
Riverside	$444,000	$507,000	$4.3m	$4,920
Mattapan	$125,000	$43,000	$8.2m	$43,120
JFK/UMass	Low	$61,000	$1.6m	$5,870
Ruggles	Low	$75,000	$1.6m	$4,760

Alewife Connection

The estimated capital cost of providing a commuter rail transfer at Alewife is $7.6 million. This would be $7,410 per transfer trip or $21,700 per new transit trip. In these measures, it would be one of the least cost-effective transfer projects examined.

Operating costs for an Alewife transfer station would be low. The extra distance and running time would result in slight increases in fuel and maintenance costs. The new commuter rail platform at Alewife would also require some cleaning and maintenance. Larger expenses could be incurred if the amount of new ridership generated by the connection were great enough to require running longer or more frequent trains than would be needed in the no-build case.

Wonderland Connection

The estimated capital cost of providing a rapid transit/commuter rail connection near Wonderland is $9.3 million. This cost includes extending Blue Line tracks 0.36 miles and constructing a new station. The $9.3 million would represent a cost of $8,630 per new transit trip. In this measure, a Wonderland connection would be one of the more cost-effective projects examined in the PMT.

The extra distance and running time from the present Wonderland terminal to the new transfer station would increase Blue Line operating costs by $461,000 per year. New fare revenue generated by the transfer would amount to $247,000, or 54 percent of the incremental operating costs. (Increased commuter rail operating costs resulting from the transfer station were not estimated, but would be very low.)

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[27] Costs do not include land acquisition.

Riverside Connection

The capital cost to provide a Riverside connection would be $4.3 million. (This assumes that the D Line would still be operated as a Green Line branch rather than being replaced by a Blue Line extension.) The average capital cost per new weekday Green Line rider and per new transit rider would be $4,920. This is far less than the average capital cost per new rider for all PMT projects.

The extra distance from the present D Line Riverside Station to the transfer station, combined with extra dwell time at the new station, would increase round trip running time by 2.5 minutes. If all service were extended through, D Line operating costs would increase by $444,000 per year. (Increased commuter rail operating costs resulting from the transfer station were not estimated but would be very low.) At the predicted demand levels, incremental revenue ($507,000) would exceed incremental Green Line operating costs by $63,000.

Estimated travel time savings for a Riverside transfer (576 hours per weekday) are higher than those of about half the other PMT projects examined. With the predicted 875 weekday riders, the total cost per hour of travel time savings would be among the lowest of all PMT projects, at $0.46.

Mattapan Connection

The connection between the Red Line and the Fairmount Line would be implemented only if the Mattapan High Speed Line were replaced by an extension of the Red Line. That conversion, analyzed as a separate PMT project, would cost approximately $54.8 million. The construction of the additional one-quarter mile extension to the Fairmount Line and a new terminal station would add $8.2 million to the cost.

Additional operating costs attributable to the short extension of the Red Line from Mattapan would be approximately $125,000 per year. Additional commuter rail costs would be negligible. The connection would generate $43,000 per year in new fare revenue, or slightly more than one third of its operating costs. The capital cost per new transit rider, at $43,120, is the highest of the six transfer projects examined.

JFK/UMass Connection

Because the Old Colony right of way adjoins that of the Red Line, no track extension would be needed to provide a transfer station at JFK/UMass. Some modifications to the bus lanes used by the free UMass shuttle buses and several local MBTA routes would be required to make room for a commuter rail platform. The PMT capital cost estimate for a JFK/UMass commuter rail station is $1.3 million. The capital cost per new transit trip would be only $5,870. This would make this one of the most cost-effective of the PMT projects in this measure.

Ruggles Connection

The estimated capital cost of adding a platform to Track 2 at Ruggles Station would be at least $1.6 million. It would probably be much higher because of unusual complications at this site. Ruggles Station is in an open cut with vertical retaining walls on both sides. There is no room for another platform within the cut, so provision of a platform on Track 2 would likely entail major reconstruction.

The average capital cost of $4,760 per new weekday transit rider would be far below the PMT project average. At the predicted demand levels, revenue would exceed the sum of operating costs and annualized capital costs.

Air Quality Impacts

The rapid transit/commuter rail connections would all have low air quality benefits, with each resulting in a reduction in regional emissions of 0.01 percent or less (see Table G-57). However, because most of the projects have relatively low capital costs, the capital cost per kilogram of VOC eliminated would be below average.

Table G-57
Air Quality Impacts of New Rapid Transit/Commuter Rail Connections

	% Reduction Regional Emissions	Capital Cost/kg of VOC Elim/weekday
Alewife Connection	0.01%	$1,614,000
Wonderland Connection	0.01%	$982,800
Riverside Connection	0.01%	$708,600
Mattapan Connection	<0.01%	$5,981,000
JFK/UMass Connection	0.01%	$286,300
Ruggles Connection	<0.01%	$460,600

Other Impacts

The rapid transit and commuter rail connections would have a number of impacts on rapid transit and commuter rail operations, and on existing riders. The most important of these are as follows:

JFK/UMass Connection

A JFK/UMass transfer station could cause operational problems for the Old Colony Lines. The restored Old Colony service will have only one track for most of the distance between Boston and Braintree. This will include the segment containing the JFK/UMass Station. To maintain peak-period schedules, it will be necessary for trains to run between Braintree and Boston with a minimum of delays. Trains from at least two and possibly three commuter rail routes will be sharing this track.

A station stop at JFK/UMass would increase running times. Further, variation in dwell times at the station would make these running times less predictable, which could affect reliability. Given the relatively small amount of new transit ridership that would be attracted, a JFK/UMass Old Colony Station does not appear to warrant the potential adverse impacts on reliability.

Ruggles Connection

The addition of a commuter rail platform on Track 2 at Ruggles Station, would increase flexibility of train operations. At present, trains scheduled to stop at Ruggles must be routed via Track 1 or Track 3. A Track 2 platform would allow diversion to Track 2 of inbound trains stopping at Ruggles when necessary to compensate for delays on the other tracks.

Any new stop added to a route increases running times between stations on opposite sides of it because of the extra acceleration, deceleration and dwell times. This impact would be particularly large at Ruggles, because of the high speed limit on Track 2. At present, inbound Attleboro/Stoughton trains are scheduled to take four to five minutes longer between Hyde Park and Back Bay when stopping at Ruggles than when not stopping there. Therefore, a stop at Ruggles would produce a significant disbenefit for passengers destined for Back Bay or South Station.

In the 1989 counts, 5,357 passengers alighted at Back Bay or South Station in the AM peak from Attleboro, Stoughton, or Providence trains that did not stop at Ruggles. A four-minute increase in running time would have increased travel times for these passengers by 357 hours per day, or 89,285 hours per year. With the four percent projected ridership increase on this line from 1989 to 2020, this would grow to 92,850 hours.

To get to Ruggles Station from trains that don't stop there, passengers must alight at Back Bay and travel back two stops on the Orange Line. This adds about ten minutes to their travel times compared to alighting directly at Ruggles. An estimated 840 passengers would ride to Ruggles on Attleboro, Stoughton or Providence trains in 2020 on trains that would only be able to stop there with a Track 2 platform. For these passengers, travel time savings from a direct stop at Ruggles would be 140 hours per day, or 35,000 hours per year. Even adding a 10-minute penalty for the perceived inconvenience of transferring at Back Bay, the savings for these passengers would be smaller than the increases for Back Bay and South Station passengers.

Conclusions

Alewife Connection

A transfer connection between the Fitchburg commuter rail line and the Red Line at Alewife would be one of the less costly PMT projects. However, it would have relatively limited transportation and environmental benefits. Because there is already a transfer connection between the two lines at Porter Square (1.5 miles from Alewife), the potential of an Alewife transfer for attracting new transit riders is limited.

Wonderland Connection

The Wonderland connection would be the best of any of the connections examined. It would serve a total of 7,200 trips per weekday, which would be higher than current ridership at half of the existing Blue Line stations. The connection would be used mostly by passengers traveling between points on the Rockport/Ipswich Line north of Wonderland and points near downtown Boston Blue Line stations. Without the Wonderland connection, most of these passengers would ride Rockport/Ipswich trains to North Station and continue from there on foot or via the Orange or Green Lines. The total would, however, include about 1,080 weekday diversions from automobiles.

The connection would cost approximately $9.3 million. In terms of the amount of new ridership attracted, and the air quality benefits, this would be a cost-effective project.

Riverside Connection

A transfer connection between the Framingham commuter rail line and the Green Line at Riverside would be among the least costly PMT projects, but would have relatively limited transportation and environmental benefits. Such a station would also have little potential for attracting new non-transfer commuter rail riders. Discontinuance of Auburndale Station, assumed as part of the project, would make service less convenient for most of the 220 present users of that station.

Mattapan Connection

The year 2020 demand forecasts indicate that a connection between the Red Line and the Fairmount Line would serve the second-largest number of passengers of any of the connections examined (1,680 total trips per weekday), but the smallest number of new transit riders (189). These figures include only commuter rail ridership at the Mattapan transfer station. Practically all of this ridership would be attracted regardless of whether the station included a Red Line connection. Consideration should be given to constructing a station just for the commuter rail line at the transfer station site, as the cost would be far less than that of a project including a Red Line extension and station.

The demand forecasts did not indicate how many Red Line boardings would take place at a Mattapan transfer station, but did indicate that there would be no net ridership increase compared to an extension ending at the present Mattapan Station. Therefore, the possibility of an extension to the Fairmount Line would not increase the merits of replacing the High Speed Line with a Red Line extension to Mattapan.

JFK/UMass Connection

A transfer connection between the Old Colony commuter rail lines and the Red Line at JFK/UMass would have relatively limited transportation and environmental benefits, even using the most optimistic demand projections. Such a station could have a substantial negative impact on Old Colony service reliability because of scheduling constraints imposed by single track. Given the relatively small amount of new transit ridership that would be attracted, a JFK/UMass Old Colony station does not appear to warrant the potential adverse schedule impacts.

Ruggles Connection

Based on the ridership patterns for commuter rail trains that now stop at Ruggles, a Track 2 platform would be used mostly by passengers with final destinations in the vicinity of the station rather than by Orange Line transfer passengers. Adding a Ruggles stop for trains that now run through this station would increase running times to Back Bay and South Station by four to five minutes. The travel time increase for through passengers would exceed the savings for passengers alighting at Ruggles.

Inner Harbor Ferry Services

This section summarizes the results of the PMT analysis of providing new inner harbor ferry services to Charlestown, Downtown Boston and Logan Airport. The alternatives presented are based on the premise that harbor ferry services would be designed or revised to provide more direct service than rapid transit and local bus service.

Existing Conditions

Current Inner Harbor Ferry Services

Currently, inner harbor ferry service is operated from Long Wharf to Charlestown Navy Yard and from Rowe's Wharf to Logan Airport. The Long Wharf to Charlestown Navy Yard service is operated by Boston Harbor Cruises under contract to the MBTA. Funding for this service is provided by the Massachusetts Highway Department. Weekday service operates from 6:30 a.m. to 8:00 p.m. with departures every fifteen minutes between Long Wharf and the Navy Yard during peak periods and every one-half hour during off peak periods. More abbreviated service is provided on Saturday and Sunday.

The water ferry service between Rowe's Wharf and Logan Airport is operated by Beacon Management Company with subsidization provided by Massport through the end of 1993. The service provides a seven minute trip between Rowe's Wharf and Logan Airport. Service is provided every fifteen minutes from 6:00 a.m. to 8:00 p.m. on weekdays and every thirty minutes between noon and 8:00 p.m. on Sundays. At the airport, the ferry is met by a free Massport shuttle bus which stops at all Logan terminals. The ferry serves over 140,000 passengers annually.

Gaps in Existing Coverage

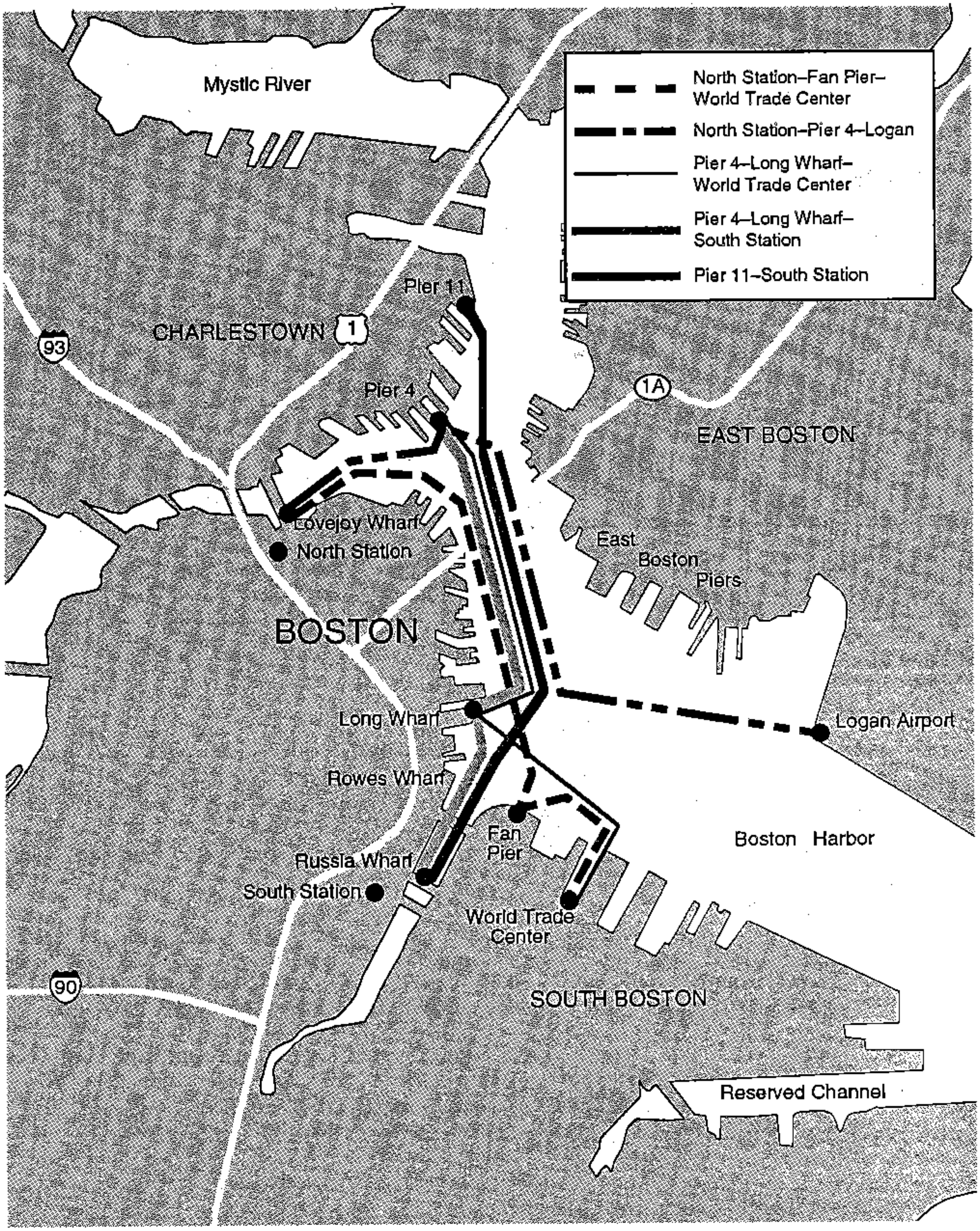
Inner harbor water ferry service currently serves the Long Wharf, Rowe's Wharf, Charlestown Navy Yard and Logan Airport areas. Potential areas for new services include the Fan Pier area of South Boston where a new Federal Courthouse will be constructed and South Boston Pier 5 where the World Trade Center will be expanded. There is also no ferry service at either South Station or North Station, both of which serve as commuter rail terminals and rapid transit stops.

PMT Alternatives

Potential new services would be designed to provide service to and from the locations identified above: North Station (Lovejoy Wharf), South Station (Russia Wharf), Fan Pier, and the World Trade Center. Because of the downtown waterfront locations, new park and ride lots would be not provided at the station locations. Parking would be provided near Lovejoy Wharf by the North Station parking garage and by existing private parking facilities at Fan Pier, World Trade Center and the Charlestown Navy Yard. However, parking fees at these lots would be market-based and much higher than at suburban MBTA lots. As a result, it is not expected that they would attract park-and-ride ferry passengers.

These services, which are shown in Figure G-34, would be as follows:

Figure G-34
Proposed Inner Harbor Ferry Services



North Station to World Trade Center via Fan Pier

This ferry service would provide connections from the North Station area (Lovejoy Wharf) to South Boston. South Boston dockings would be at Fan Pier and World Trade Center. The assumed frequency of service would be every 15 minutes in the peak periods and every hour in the off-peak periods.

North Station to Logan Airport via Charlestown Navy Yard

This ferry service would provide a water connection from the North Station area to Logan Airport with an intermediate stop at the Charlestown Navy Yard (Pier 4). The assumed frequency would be every 15 minutes during the peak periods and every hour during off-peak periods.

Charlestown Navy Yard to South Station via Long Wharf

This ferry service would provide a water connection between South Station and the Charlestown Navy Yard (Pier 4) with an intermediate stop at Long Wharf. Russia Wharf, adjacent to South Station, would provide connections to the Red Line, commuter rail and the South Station bus terminal. The Long Wharf dock would provide a connection for passengers to the Blue Line Aquarium station and be within walking distance of the Financial District. The assumed frequency would be every 15 minutes during the peak periods and every hour during off-peak periods.

Charlestown Navy Yard to World Trade Center via Long Wharf

This ferry service would provide an extension of the existing water service from the Charlestown Navy Yard (Pier 4) to Long Wharf. The service would continue to the World Trade Center in South Boston. The assumed frequency would be every 15 minutes during the peak periods and every hour during off-peak periods.

Charlestown Navy Yard Pier 11 to South Station

This ferry service would provide a water connection between South Station (Russia Wharf) and Charlestown Navy Yard (Pier 11). The assumed frequency would be every 15 minutes during the peak periods and every hour during off-peak periods. This service would connect the South Station Transportation Center, serving the Red Line, commuter rail, and the bus terminal, with the Charlestown Navy Yard. In addition, it would provide ferry service to the northern end of the Navy Yard at Pier 11 where additional development is anticipated.

Ridership Impacts

Ridership projections for all the Inner Harbor ferry service alternatives examined indicate that very few (less than 25) new transit trips would be generated in each case (see Table G-58). (These diversions are insignificant, especially when modeling is being done in a regional context.) The results indicate that most of the ridership would represent diversions from other transit services.

The five harbor ferry routes examined showed limited new ridership levels. Most of the riders projected to use the water shuttle ferries are those who currently now ride either a local MBTA bus or rapid transit. This lack of new ridership may be attributable to three main factors. First, while the ferry locations are near work-related sites, they would not directly serve heavily populated residential locations. Second, a lack of land-based transit connections means that trips could not be easily made to and from those residential areas by transferring from other transit services. Third, the cost of parking in downtown Boston near the proposed ferry terminal is relatively expensive. The high cost of parking would deter commuters that might park-and ride.

Table G-58
Ridership Impacts of Harbor Ferry Improvements/Expansion

Ferry Route	Total Trips	New Transit Trips
North Station–Fan Pier–World Trade Center	1,380	less than 25
North Station–Navy Yard Pier 4–Logan Airport	710	less than 25
Navy Yard Pier 4–Long Wharf–South Station	1,050	less than 25
Navy Yard Pier 4–Long Wharf–World Trade Center	380	less than 25
Navy Yard Pier 11–South Station	830	less than 25

Costs and Cost-Effectiveness

Capital costs for each of the harbor ferry routes would range from $1.36 million to $2.1 million (see Table G-59), with the majority of costs being for the purchase of new ferryboats. These costs do not include the cost of new docking facilities at North Station (Lovejoy Wharf) and South Station (Russia Wharf). It was assumed that these two facilities would be completed as separate projects.

Table G-59
Capital Cost of Harbor Ferry Improvements/Expansion

Ferry Route	Capital Cost
North Station–Fan Pier–World Trade Center	$2,089,000
North Station–Navy Yard Pier 4–Logan Airport	$1,702,000
Navy Yard Pier 4–Long Wharf–South Station	$1,410,000
Navy Yard Pier 4–Long Wharf–World Trade Center	$1,713,000
Navy Yard Pier 11–South Station	$1,358,000
Total	$8,272,000

Because of the low ridership estimates for new riders, the capital cost per new rider would be very high.

The five new ferry services would increase operating costs by $638,000 to $2,045,000 per year. The increased fare box revenue would be marginal because the overwhelming majority of the ridership would be diverted from another form of transit.

Table G-60
Cost-Effectiveness of Harbor Ferry Improvements/Expansion

Ferry Route	Annual Operating Cost
North Station–Fan Pier–World Trade Center	$1,555,000
North Station–Navy Yard Pier 4–Logan Airport	$1,348,000
Navy Yard Pier 4–Long Wharf–South Station	$1,138,000
Navy Yard Pier 4–Long Wharf–World Trade Center	$2,045,000
Navy Yard Pier 11–South Station	$638,000
Total	$6,724,000

Air Quality Impacts

Each of the five harbor ferry routes would have negligible air quality benefits (because of the small number of new transit riders).

Conclusions

The PMT analysis of five possible new ferry routes in the Boston Inner Harbor indicates that their riders would be diverted mostly from other transportation services. Consequently, the ferry routes would have high capital costs per new transit rider, and would have negligible air quality benefits.

The demand potential for such ferry service for work trips would be limited by the lack of residential areas within convenient walking distances of the ferry terminals, and by distances from the waterfront to the majority of work locations. Dedicated shuttle buses providing collection and distribution at both ends of the ferry routes could increase demand, but the cost and revenue impacts of such services were not analyzed.

For the routes examined, the differences in trip distances by water and by highway would be too small to allow the ferries to achieve travel time savings compared to auto travel.[28] (High-speed ferry operation within the Inner Harbor is not feasible because of conflicts with other marine traffic.)

Massport and the Central Artery project have released a Request for Proposals (RFP) to perform further study on the demand for inner harbor water ferry service. This study should provide a more in-depth look at demand and routings than this initial study as part of the PMT. It is recommended that ridership demand and the need for supporting transit services, such as shuttle buses, be further studied before any additional inner harbor water ferry service is instituted.

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[28] The most successful ferry services are those that operate either in areas where geographical barriers make highway distances much longer than the ferry routes, or where highway congestion allows ferries to be time-competitive.

Inner Circumferential Transit

Existing Conditions

Boston has a large number of trip generators located beyond the central core. Many of these trip generators—UMass/Boston, Newmarket, the South End Medical Area, the Ruggles area, the Longwood Medical Area, Boston University, MIT, Kendall Square and Lechmere—ring the core. As these areas have grown, the demand for transit to, from, and between these areas has also grown. In response, a number of studies have been undertaken to examine the potential for new circumferential transit services. Most recently, the MBTA has undertaken a "Crosstown Transit Feasibility Study" to further examine bus options. In addition, the City of Boston is conducting its own "Crosstown Transit" study, and the Boston Society of Architects has recently begun to examine the concept of a "New Urban Ring."

The draft version of the MBTA's Crosstown Transit Feasibility Study will recommend the implementation of new bus routes to improve circumferential bus service in the short and mid term. The study indicates that such service would provide significant benefits for current riders and bring new riders onto the system, both by drawing people out of automobiles, and also by serving new economic development in the circumferential ring. The MBTA is now reviewing this study, but based upon the preliminary results, hopes to implement new bus ervice in the circumferential corridor during calendar year 1994.

The bus service would consist of new routes offering limited-stop service in two circumferential corridors, TSM improvements to reduce delays, and the development of improved bus stop facilities for circumferential service. These bus routes would connect Cambridge, Boston University, the Longwood Medical Area, Ruggles, the South End Medical Area, and Andrew Square.

Running these new routes would require the purchase of nine new buses, entailing a capital cost of $1.8 million. In addition, roughly twenty-five passenger shelters/bus stations would be constructed, costing between $500,000 and $1,000,000 in total. The service would have a net operating cost of approximately $1.5 million annually, and carry approximately 7,500 daily riders.

Additional details on the new crosstown bus service will be available when the draft study is distributed in final form, which is expected in January or February, 1994.

PMT Alternatives

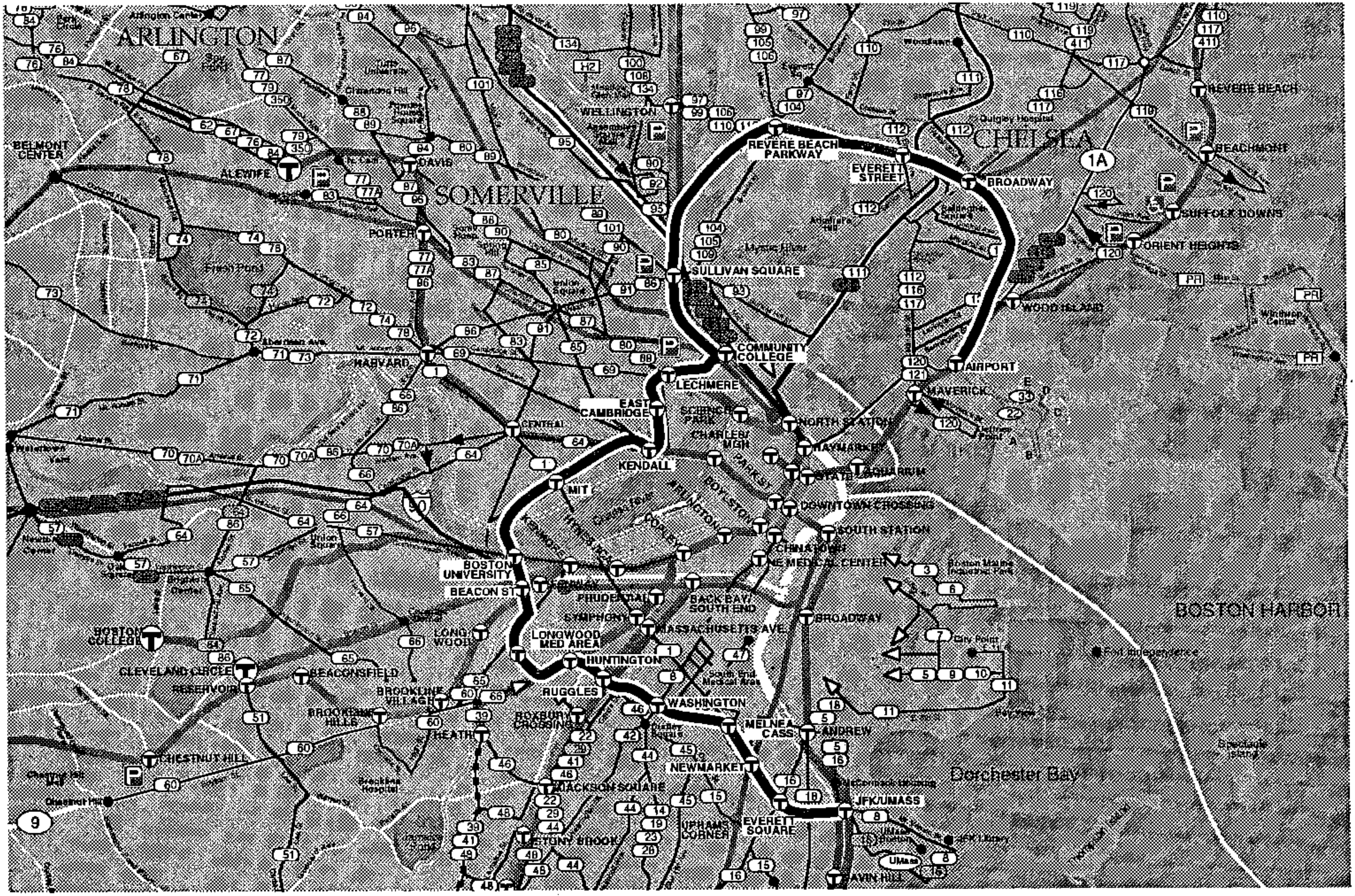
The PMT analysis included an examination of two Light Rail Transit (LRT) alternatives:

1. Sullivan Square – Ruggles ("Core LRT")

2. Logan Airport – JFK/UMass ("Full LRT")

The Logan Airport to JFK/UMass alternative is the same as Alternative 3E from the MBTA's "Draft Circumferential Transit Feasibility Study," and is shown in Figure G-35. The Sullivan Square – Ruggles alternative is the middle section of the full alternative. It is similar to Alternative 3C in the MBTA report but includes an additional segment from

Figure G-35
Inner Circumferential Transit: Full LRT Alternative



Community College to Sullivan (see Figure G-36). The Community College to Sullivan segment was included so that park and ride commuters from I-93 could be served.

Both LRT alternatives would use technology similar to the Green Line (but with low-floor cars). Also for both alternatives, all trains would operate the full length of the line at four minute headways during peak periods, and at eight minute headways during off-peak periods.

Note that the intent of including these alternatives was to test the concept of circumferential transit, rather than to select a specific mode or alignment. These alternatives are not intended to either endorse these alignments or preclude others; subsequent analysis to examine other alignments and modes would be required before any rail circumferential transit could be constructed.

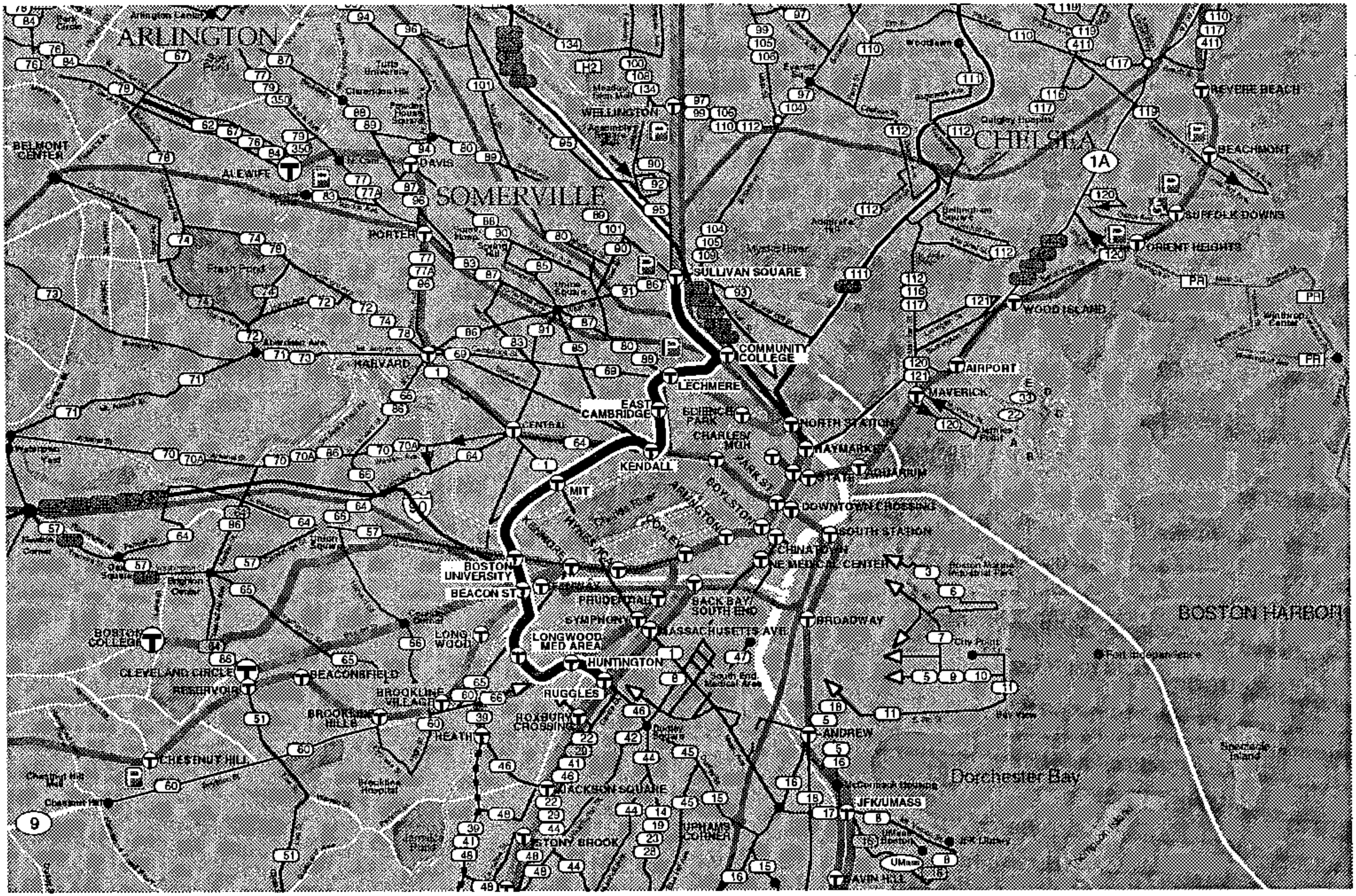
1. Full LRT: Logan Airport – JFK/UMass

The full alternative would operate 13.3 miles between Logan Airport and JFK/UMass Station through East Boston, Chelsea, Everett, Charlestown, Cambridge, the Fenway, Roxbury, and Dorchester. There would be a total of 20 stations providing local access and connections to all rapid transit and commuter rail lines.

From south to north, stations would be located as follows:

JFK/UMass, with connections to the Red Line.
Edward Everett Square, near the intersection of Boston Road and Columbia Road.
Newmarket, at Massachusetts Ave. with connections to the Fairmount Line.
Melnea Cass, at the intersection of Melnea Cass Boulevard and Massachusetts Ave.
Washington, at the intersection of Melnea Cass Boulevard and Washington Street near Dudley Square, and with connections to Washington Street replacement service.
Ruggles, with connections to the Orange Line, and to the Stoughton, Attleboro, Franklin, and Needham commuter rail lines.
Huntington, at the intersection of Huntington Ave. and Ruggles Street, with connections to the E/Arborway branch of the Green Line.
Longwood Medical Area, on Longwood Avenue near Binney Street.
Beacon Street, on Park Drive near Beacon Street, with connections to the C/Cleveland Circle and D/Riverside branches of the Green Line, and the Framingham commuter rail line.
Boston University, at Commonwealth Ave. near Saint Mary's Street, with connections with the B/Boston College branch of the Green Line.
MIT, at Massachusetts Ave. near Vassar Street.
Kendall, with connections to the Red Line.
East Cambridge, in the vicinity of the Galleria Mall.
Lechmere, with connections to the Green Line, and with limited parking.
Community College, with connections to the Orange Line and all northside commuter rail lines (Fitchburg, Lowell, Haverhill/Reading, and Rockport/Ipswich).
Sullivan, with connections to the Orange Line and with parking.
Revere Beach Parkway in Everett at the intersection of Revere Beach Parkway and Broadway, with parking.
Everett Street in Chelsea, with parking
Broadway in Chelsea, with connections to the Rockport/Ipswich Line, and with parking.
Airport, with connections to Logan Airport and the Blue Line.

Figure G-36
Inner Circumferential Transit: Core LRT Alternative



The core section of the alignment between Sullivan Square and Ruggles would be fully grade-separated and would operate in an exclusive right-of-way. The northern segment between Sullivan and Logan Airport would operate in railroad rights-of-way with some at grade crossings. The southern segment between Ruggles and JFK/UMass would operate in a combination of exclusive rights-of-way and in roadway medians (with a number of at-grade crossings). In more detail, the alignment would be as follows:[29]

JFK/UMass – Ruggles

From JFK/UMass, the line would operate on an aerial structure over the Southeast Expressway to Dorchester Ave where it would descend into the median of Columbia Road. The line would continue in the median of Columbia Road to a stop at Everett Square, and then would operate in the median of Mass Ave through Newmarket to approximately Magazine Street. It would then enter a subway until Harrison Avenue and then operate in the median of Melnea Cass Boulevard to Ruggles Station. Stations would be located in the subway portion at the intersection of Melnea Cass Boulevard and Massachusetts Ave. ("Melnea Cass" station) and on the surface at Melnea Cass Boulevard and Washington Street ("Washington" station).

Ruggles – Sullivan

From Ruggles Station, the line would operate along a transit easement on Ruggles Street, enter a subway portal near Huntington Avenue and continue through the Longwood area in a subway. Stations would be at Huntington Avenue, where connections could be made with the E/Arborway branch of the Green Line, and in the Longwood Medical Area. From the Longwood Medical Area, the line would be in a subway which would run generally under Park Drive, then under Boston University and the Charles River. One station would be located along Park Drive near Beacon Street ("Beacon" Station), providing connections to both the C/Cleveland Circle and D/Riverside branches of the Green Line, as well as to a new station on the Framingham commuter rail line. Another station would be located at Boston University at Commonwealth Avenue, where there would be connections with the B/Boston College branch of the Green Line.

In Cambridge, the line would continue in a subway beneath the Grand Junction railroad right-of-way to an MIT Station at Massachusetts Ave., then to Broadway and beneath Broadway to Kendall Station, where there would be connections with the Red Line. From Kendall, the subway would continue around the Badger Building and intersect Second Street at Athenaeum Street, where a portal would bring the line to grade. From there to Thorndike Street, Second Street would be converted to a transit mall, and there would be one stop near the Galleria Mall ("East Cambridge" Station). At Thorndike Street, the line would re-enter a subway to Lechmere Station, where connections could be made with the Green Line.

From Lechmere, the line would rise to the surface and then to an elevated structure parallel to the Gilmore Bridge. A new station would be constructed above the existing Community College Station, which would provide connections to the Orange Line and all northside commuter rail lines. From Community College to Sullivan, the line would parallel the existing Orange Line. At Sullivan, connections could be made to the Orange Line, and parking would be provided.

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[29] Much of this information is taken from the "Draft Circumferential Transit Feasibility Study," which was prepared for the MBTA by TAMS Consultants, Inc., May 1989. Refer to that report for additional information.

Sullivan – Airport

From Sullivan, the line would operate in the Eastern Route right-of-way (parallel to the Rockport/Ipswich commuter tracks) until the vicinity of Chelsea station. Along this segment, there would be three stations: at the intersection of Broadway and Revere Beach Parkway ("Revere Beach Parkway" station), at Everett Street, and at the Chelsea commuter rail station ("Broadway" station). Connections to the Rockport/Ipswich Line would be available at Broadway. From there, the line would follow an abandoned portion of the Conrail Grand Junction right-of-way to the Chelsea River. Chelsea River crossing options include a bridge or a tunnel. The TAMS report assumed that the crossing would be made via a new bridge. However, a tunnel would likely be necessary to avoid conflicts with shipping. Across the river, the line would follow existing Conrail and Boston and Maine rights-of-way to a terminal adjacent to the existing Airport Station, where connections could be made to the Blue Line and Logan Airport.

2. Core LRT: Sullivan – Ruggles

This alternative would be a short variation of the full alternative that would operate only along the 7.3 mile Sullivan – Ruggles segment. The alignment would be identical to the Sullivan – Ruggles segment described above for the full alternative.

Ridership Impacts

Both LRT alternatives would carry high ridership: 149,530 total trips on the full alignment between Logan Airport and JFK/UMass, and 86,700 on the core segment between Sullivan and Ruggles (see Table G-61). The full alignment would attract 34,380 new transit trips, and the core segment would attract 18,200 new transit trips. The 34,380 new trips attracted by the full alignment is the largest number of new trips that would be attracted by any project examined in the PMT. The 18,200 new transit trips attracted by the core segment would be the third largest number of new transit trips attracted.

Table G-61
Ridership Impacts of Inner Circumferential Transit LRT Alternatives

	Total Trips	New Transit Trips
Full LRT (Airport - JFK/UMass)	149,530	34,380
Core LRT (Sullivan - Ruggles)	86,700	18,200

Total ridership would be much higher on the core segment than on either of the two ends beyond Sullivan and Ruggles (see Table G-62). Of the 62,830 additional trips that would be carried by the full alignment, 23,460 of the new boardings would be on the southern end between Ruggles and JFK/UMass, 12,550 would be at stations on the northern end between Sullivan and Logan Airport. The remainder would be new boardings attracted to core stations for trips to the outer ends.

Although total ridership would be much higher at core stations, nearly as many of the new transit trips would be attracted by the outer end services. This is because the core area is more intensely served by the existing system. As a result, while many existing trips could be made more conveniently with a circumferential LRT line, they can still be made relatively easily on existing rapid transit lines. The areas surrounding the outer ends however, are less well served by the existing system, and a circumferential LRT line would provide a greater improvement in service. In these areas, the markets are smaller, and therefore, total ridership would be lower, but a larger proportion of these trips would be new transit trips (26 percent versus 21 percent).

Table G-62
Inner Circumferential Transit LRT Alternatives:
2020 Weekday Station Boardings

	Full LRT	Core LRT
JFK/UMass	9,380	—
Everett Square	2,190	—
Newmarket	5,580	—
Melnea Cass	8,600	—
Washington	3,580	—
Ruggles	19,150	12,840
Huntington	12,810	7,660
Longwood Medical Area	5,480	5,510
Beacon Street	14,910	12,180
Boston University	13,480	13,180
MIT	12,760	11,250
Kendall	12,150	11,590
East Cambridge	1,940	1,760
Lechmere	4,430	3,200
Community College	5,900	5,250
Sullivan	2,920	2,280
Revere Beach Parkway	650	—
Everett Street	2,260	—
Broadway	4,390	—
Airport	5,250	—
Total	149,530	86,700

Impacts on Other Services

A circumferential LRT line would have a number of impacts on other MBTA services. In summary:

- Green Line ridership would decline by 25,250 trips per weekday. This decline would be due to diversions from the Green Line to the Circumferential Line. The Green Line Central Subway is approaching capacity; a circumferential LRT line would alleviate this problem to a certain degree.

- Red Line ridership would decrease by 6,890 trips per weekday, Blue Line ridership would decrease by 6,450 trips per weekday, and Orange Line ridership would decline by 16,750 trips per weekday. As with the Green Line, these declines would be due to diversions to the circumferential line.

- Commuter rail ridership would increase by 2,480 trips per weekday. This increase would occur primarily as a result of the connection between southside commuter rail lines and the circumferential line at Ruggles. This would greatly improve access from commuter rail to Cambridge, Boston University, and the Longwood Medical Area. The northside connection at Community College would be used for 2,800 trips per weekday, but only 360 of these would be new trips.

- Local bus ridership would decrease by 49,700 trips per weekday. These would be trips that would be diverted to the circumferential rail line from bus routes that would be replaced by the rail line.

Costs and Cost-Effectiveness

The construction of a circumferential rail line would be a major undertaking that would likely have significant construction impacts, including construction of a new subway along most of the core alignment, new stations, connections to existing lines, and various roadway changes in the vicinity of new stations. The costs used for the PMT analysis are estimated 1993 dollars based on information contained in the Circumferential Transit Feasibility Study, updated to include more recent data where available.[30] Capital costs for the two alternatives, excluding land acquisition, would be $1.4 billion for the full alignment, and $1.1 billion for the core alignment (see Table G-63). Note also that these costs assumed that the Chelsea Creek crossing would be made via a bridge. As previously mentioned, a tunnel would likely be necessary to avoid conflicts with shipping. The potential costs for land acquisition and a tunnel under Chelsea Creek could add significantly to the cost of the full LRT alternative.

Without making any allowance for the above cost factors, the capital cost per new weekday transit rider would be $41,630 for the full alignment, and $59,200 for the core alignment. The cost per new rider is lower for the full alignment because capital costs are significantly lower for the two outer ends where service would be at-grade. Both of these costs are relatively high (of projects that would generate significant ridership increases, few would be higher).

Table G-63
Cost-Effectiveness of Inner Circumferential LRT Alternatives

	Operating Cost (Annual)	Fare Revenue (Annual)	Capital Cost[31]	Capital Cost/ New Trip
Full LRT (Airport - JFK/UMass)	$13.7m	$6.1m	$1.4b	$41,600
Core LRT (Sullivan - Ruggles)	$4.9m	$3.2m	$1.1b	$59,200

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[30] For additional information on physical and construction impacts, see Chapter VIII of the Circumferential Transit Feasibility Study. For additional information on costs, see Chapter IX.

[31] Costs do not include land acquisition.

The full LRT alignment would increase operating costs by $13.7 million per year, while the core alignment would result in a much lower increase of $4.9 million. The full alignment would generate $6.1 million, or 45 percent of its operating costs, in new revenue. The core alignment would perform better, generating 66 percent of its costs in new revenue.

Air Quality Impacts

Both of the LRT alternatives would have a relatively large positive benefit on regional emissions. The core alignment would reduce regional emission by 0.17 percent; the full alignment would increase the reduction to 0.22 percent (see Table G-64). These are the largest benefits that would be attainable by any single project except the North Station - South Station Rail Link (which would reduce emissions by up to 0.54 percent). Circumferential rail line air quality impacts would be lower than for the Rail Link even though more trips would be served, because the new circumferential trips would be much shorter.

The cost to these benefits would be high, at $7.6 to $7.8 million per kilogram of VOC eliminated per weekday. These are among the highest of such costs for all projects that would have significant air quality benefit. They would be exceeded only by the costs of a conversion of the Riverside branch of the Green Line to Blue Line service.

Table G-64
Air Quality Impacts of Inner Circumferential LRT Alternatives

	% Reduction Regional Emissions	Capital Cost/kg of VOC Elim/weekday
Full LRT (Airport - JFK/UMass)	0.22%	$7,771,000
Core LRT (Sullivan - Ruggles)	0.17%	$7,629,000

Conclusions

Either circumferential LRT alternative could attract a large number of new transit trips and make service more convenient for existing riders. The full alignment would serve a total of 149,530 trips per weekday of which 34,380 trips would be new transit trips. The core alignment would serve 86,700 total trips per weekday, of which 18,200 would be new transit trips. The 34,380 new trips attracted by the full alignment would the largest number of new trips that would be attracted by any project examined in the PMT. The 18,200 new transit trips attracted by the core segment would be the third largest number of new transit trips attracted, following only the full alignment and the North Station - South Station Rail Link.

Construction of a new circumferential LRT line would be expensive. Not including land acquisition costs or a possible tunnel under Chelsea Creek, the full alignment would cost $1.4 billion, and the core alignment would cost $1.1 billion. Once constructed, either alternative would have a ratio of revenues to operating costs that would compare favorably with the existing system. The full alignment would generate a farebox return ratio of 45 percent; the core alignment 66 percent. (By comparison, farebox return ratios on existing rapid transit lines range from 36 to 53 percent.)

A circumferential rail line would have a significant positive impact on air quality: the full alignment would reduce regional emissions by 0.22 percent; the core alignment by 0.17 percent. These are the largest benefits that would be attainable by any single project except the North Station - South Station Rail Link, which would reduce emissions by up to 0.54 percent.

Construction of a new circumferential LRT line would also have significant construction impacts, especially along the core alignment between Sullivan and Ruggles. Although the determination of traffic impacts during construction was beyond the scope of the PMT, it is unlikely that a circumferential line could be constructed at the same time as the new Central Artery without significant adverse impacts.

In summary, the PMT analysis has confirmed that there is a significant demand for improved circumferential transit services. As a result, examination of various alignments and types of services should continue. However, unless subsequent analyses demonstrate that adverse traffic impacts could be avoided, a circumferential rail line should be considered as a long-range project for possible construction following completion of the CA/T project.

South Boston Transitway - South Station to Boylston

This section summarizes the results of the analysis of the extension of the South Boston Transitway from its Base Case terminus at South Station to the Full Build terminus at the corner of Boylston Street and Tremont Street. The analysis is drawn from the Draft Environmental Impact Statement/Supplemental Draft Environmental Impact Report for the South Boston Piers/Fort Point Channel Project (November 1992).

Existing Conditions

The 2020 Base Case scenario used in the PMT analysis assumed that the South Boston Transitway would be built from South Station to the World Trade Center in South Boston, with surface services continuing to the Boston Marine Industrial Park (BMIP) and to a cluster of development on Summer Street at D Street. Planning for this Minimum Operable Segment (MOS) alternative of the Transitway is well advanced, with the Final Environmental Impact Statement expected in the next few months. Construction is scheduled to begin in 1994, and service should be underway by 1999.

Boylston Station is currently served by all four branches of the Green Line. From the west, surface lines enter the Central Subway from Boston College, Cleveland Circle, Riverside and Heath Street and serve the length of the Back Bay before arriving at Boylston Station. North of Boylston, all lines serve Park Street and Government Center, with the C Line continuing to North Station and the E Line extending to Lechmere Station in East Cambridge.

Chinatown Station on the Orange Line is between South Station and Boylston Station along the proposed Transitway route. Orange Line trains run from Forest Hills on the south to Oak Grove on the north.

There is currently no direct transit service connecting either Boylston Station or Chinatown Station with South Station or the South Boston Piers area. To get to South Station, Green Line riders can transfer to the Red Line at Park Street, and Orange Line passengers can do the same at Downtown Crossing. Transit service directly from South Station to the Piers area is provided by local bus Routes 6 and 7. Route 7 also has a stop near the Chauncy Street entrance to Downtown Crossing.

PMT Alternative

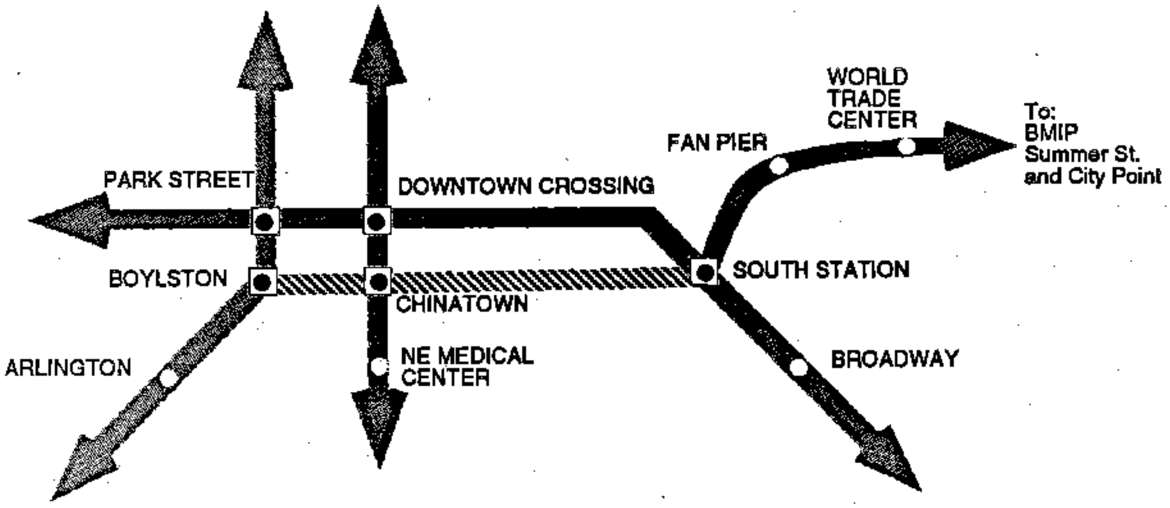
The alternative carried in the PMT analysis and studied in the DEIS/SDEIR would extend the Transitway tunnel connecting the World Trade Center to South Station westward under the Central Artery parallel to Essex Street and finally to Tremont Street at Boylston. This extension would provide transfers to the Orange Line at Chinatown Station and the Green Line at Boylston Station. A new platform and turnaround loop would be constructed one level below the existing Boylston Green Line platforms.

Three separate routes would use this Full Build tunnel. Two of the routes would be extensions of the routes contained in the Base Case project: 1) Boylston to BMIP and 2) Boylston to Summer Street. The third route, Boylston to City Point, would replace Route 7 running from Downtown to City Point via Summer Street. The first two routes would have peak period headways between 1.6 minutes and 2.6 minutes, while the third route would have a peak period headway ranging between 4.6 and 5.5 minutes.

The vehicles used for these Transitway routes would be high-capacity 60-foot articulated buses. They could be trackless trolleys, powered through electric trolley wires strung in the Transitway and along the streets on the surface, or dual-powered buses capable of operating with electric power through trolley wires inside the tunnel and with diesel power outside of the tunnel. The South Station to Boylston extension would require 20 more of these buses than would be required for the MOS (South Station to World Trade Center) project.

In addition to the routes using the Transitway, the DEIS/SDEIR proposed several supplemental bus routes to improve access and connections to the South Boston Piers area. The most important of these are a shuttle bus from North Station to the Piers area via the Surface Artery and Northern Avenue and a new local bus route from the residential part of South Boston to South Station via D Street and Congress Street.

Figure G-37
Existing Rapid Transit Lines and Base Case Transitway and Potential Transitway Extension to Boylston



Ridership Impacts

The DEIS/SDEIR provides two sets of forecasts for 2020 ridership corresponding to two different projections of employment growth in the South Boston industrial area. For the "Lower Growth" scenario, the additional ridership on the Transitway due to the extension to Boylston totals 26,850 daily trips (13,425 in each direction). Of these trips, roughly 6,500 would be new transit riders, people who would otherwise drive or walk. The rest would be diverted from other transit services such as local buses and rapid transit lines.

The "High Growth" scenario forecasts 36,000 trips due to the extension (18,000 in each direction). Of these trips roughly 7,800 would be new transit riders, with the rest coming from other transit services. This scenario is more directly comparable to the 2020 forecasts for other PMT projects.

Costs and Cost-Effectiveness

The estimated capital cost for the extension of the South Boston Transitway to Boylston is $180 million. This includes the tunneling and station costs between Boylston and South Station and the vehicle costs for providing the extended service.

Including changes in other bus service, operating costs for the Full Build project would be lower than those for the MOS - South Station to World Trade Center portion. The extension to Boylston allows for the elimination of several bus routes which would necessary for the MOS but are not for the Full Build. The annual operating cost savings under the Lower growth scenario is $456,000 and for the High growth scenario, $1.6 million.

Fare revenue under the Lower growth scenario would increase by $280,000 with the extension to Boylston, but would drop by $40,000 under the High growth scenario. The changes in fare revenue have more to do with the supplementary bus routes than they do with the Transitway itself.

At the estimated demand level for the High growth scenario, the Transitway extension to Boylston would have a capital cost per new transit rider of $23,077. In this measure, it would be less expensive than most of the rapid transit extension projects examined for the PMT. The annual cost per hour of travel time savings would be negative at -$4.05 because of the net decrease in operating costs. The numbers for the Lower growth scenario are somewhat less favorable at $27,692 and $0.07 respectively.

Air Quality Impacts

Environmental benefits for the extension to Boylston would be in the mid-range of projects examined for the PMT. Regional emissions would be reduced by 0.05 percent for the High growth scenario. The capital cost per kilogram of weekday VOC eliminated would be $4,511,957. For Lower growth, these figures are 0.04 percent and $5,652,911 respectively. The High growth cost is less than the unit cost for most of the rapid transit extensions examined, but greater than those for most of the commuter rail extension or improvement projects.

Conclusions

The current plan for transit service to the South Boston Piers area is to construct the South Station to World Trade Center segment by the end of this decade. At that point, the decision would be made whether to extend the service to Boylston station. The DEIS/SDEIR points out that the Full Build option (all the way to Boylston) is more cost-effective by a number of measures than the Minimum Operable Segment (MOS) option (stopping at South Station).

Much of the difference in operating costs between the Full Build and the MOS is due to the supplementary bus service. The extension to Boylston allows the MBTA to eliminate four shuttle bus routes and one local bus route that would be necessary under the MOS scheme.

The greatest uncertainty underlying all of these forecasts is the level of growth in the South Boston Piers area. The latest forecasts from the Metropolitan Area Planning Council suggest that growth in South Boston will be very low—lower than the "Lower growth" scenario in the

DEIS. Another unknown is the location of the Megaplex convention center and sports arena. If it is located in the Piers area, there will be a much greater need for transit service.

A decision on the South Station to Boylston extension should be postponed until the employment destiny of the Piers area is more clear.

North Station - South Station Rail Link

This section summarizes the examination of a North Station - South Station Rail Link by the Central Artery Rail Link Task Force. The information presented in this section is from the Rail Link report,[32] and other supplemental information provided by the Task Force. Additional study of North - South Rail Link alternatives is planned for this year by the Federal Transit Administration (FTA).

Existing Conditions

Currently, passenger railroad service into and out of Boston—both intercity and local—is provided by two physically isolated systems. One stretches in northerly directions from North Station at the northern edge of downtown Boston. The other serves areas to the south and west of Boston from South Station, located at downtown Boston's southern fringe. The two stations are separated by a distance of just over one mile.

Together, these two systems have eleven different rail routes serving 53 communities with a total of 101 stations. Five of the routes, with 52 outlying stations terminate at North Station; six of the routes, with 46 outlying stations, terminate at South Station. Intercity service to New York, Washington, and Chicago, now is confined to the southern system, but the northern system will also be used when Amtrak service is extended to Portland, Maine.

Central Artery Rail Link

The Central Artery Rail Link Task Force examined the feasibility of connecting the northside and southside commuter rail systems by constructing a rail link along a similar alignment as the new Central Artery. This Rail Link would be a two to four track tunnel that generally would be located below the new Central Artery (see Figure G-38). To the south, there would be two portals, one along Herald Street east of Back Bay Station, and the other in the vicinity of the railroad yards south of the West Fourth Street Bridge in South Boston. To the north, there would be one portal near the Gilmore Bridge in Somerville.

The Rail Link would have three stations: South Station, North Station, and a new "Central Station" located near the Blue Line's Aquarium Station. New underground platforms would be constructed at North and South Stations.

The Task Force envisioned that the Rail Link and associated service improvements would be implemented in two phases:

- **Phase 1** would include construction of a two track Rail Link with four track stations, with implementation of through intercity service between New York and Portland, and of electrified regional rail service between Providence and Haverhill, and between Stoughton and Lowell.
- **Phase 2** would involve expanding the Rail Link tunnel to four tracks and electrifying the remainder of the commuter rail system. Since only electrified service could operate through the Rail Link tunnel, this electrification would be necessary to provide the through-routing of northside and southside lines (as described in the next section).

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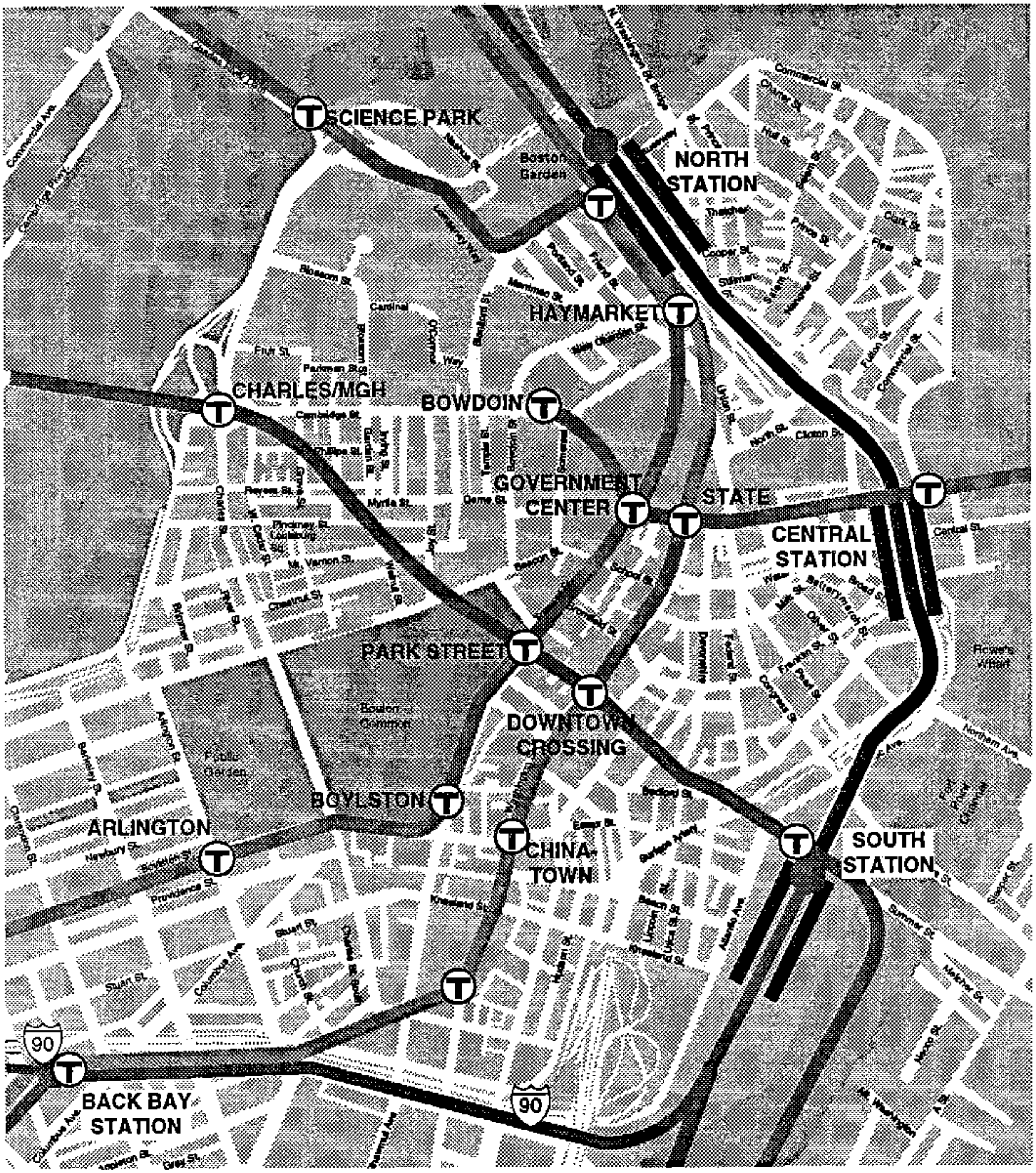
[32] "Building for an Intermodal Future: The North-South Rail Link," EOTC, May 1993.

Figure G-38
Central Artery Rail Link



Source: Central Artery Rail Link Task Force

Rail Link Service Concept

With the Rail Link, the existing commuter rail system could be upgraded from a predominantly commuter oriented service, with limited off-peak service, to an all-day service designed for a wider range of travel purposes and destinations. There would be three principal distinguishing service characteristics of a regional system with the Rail Link:

- Most local rail trips would run through the Rail Link. Inbound trips from the north would become outbound trips on the south side, and visa-versa. Northside and southside lines would be paired to facilitate regional travel.
- More frequent service would be provided. This would both strengthen peak service by providing riders with more flexibility, and make rail more attractive for non-commuter trips.
- The run-through design and frequent service would also facilitate transfers from one line to another. For many trips, this would help make service more competitive with travel by automobile.

The pairing of northside and southside routes that would be operated through the rail link would be based on a number of considerations. The most important of these would include: regional travel patterns, ridership levels, running times, geography, train lengths, and route length. Also, because the Rail Link would require electrified service, the timing of the electrification of individual commuter rail lines would be a factor. Based on these considerations, the following through rail lines were assumed for the purposes of the Rail Link analysis (see also Figure G-39).[33]

Amtrak

Intercity Amtrak service between New York and Portland would follow a route through Providence, Boston, and Haverhill. South of Boston, service would continue to operate as it now does along the Attleboro Line. From South Station, service would operate through the Rail Link and then follow the Lowell Line to Wilmington, and the Wildcat branch to the Haverhill Line.

A Line : Haverhill–Providence

The Haverhill and Attleboro lines would be combined to form the A Line. This line would use the same alignment as described above for Amtrak service.

B Line : Lowell–Stoughton

The Lowell–Stoughton Line would be a combination of the existing Lowell Line with the Stoughton branch of the Attleboro/Stoughton Line. Between Wilmington and Canton Junction, service would operate over the same trunk used by Haverhill–Providence service, which would double the effective frequency of trains along the trunk. Two large intermodal (railroad/highway/bus) facilities would be located at the points where the A Line crosses Route 128: Mishawum/Industriplex on the north and the present Route 128 station on the south.

C Line : Rockport–Plymouth

The C Line would link coastal communities to the north and south of Boston. The main axis of the C Line would run from Plymouth to Boston and then proceed north to

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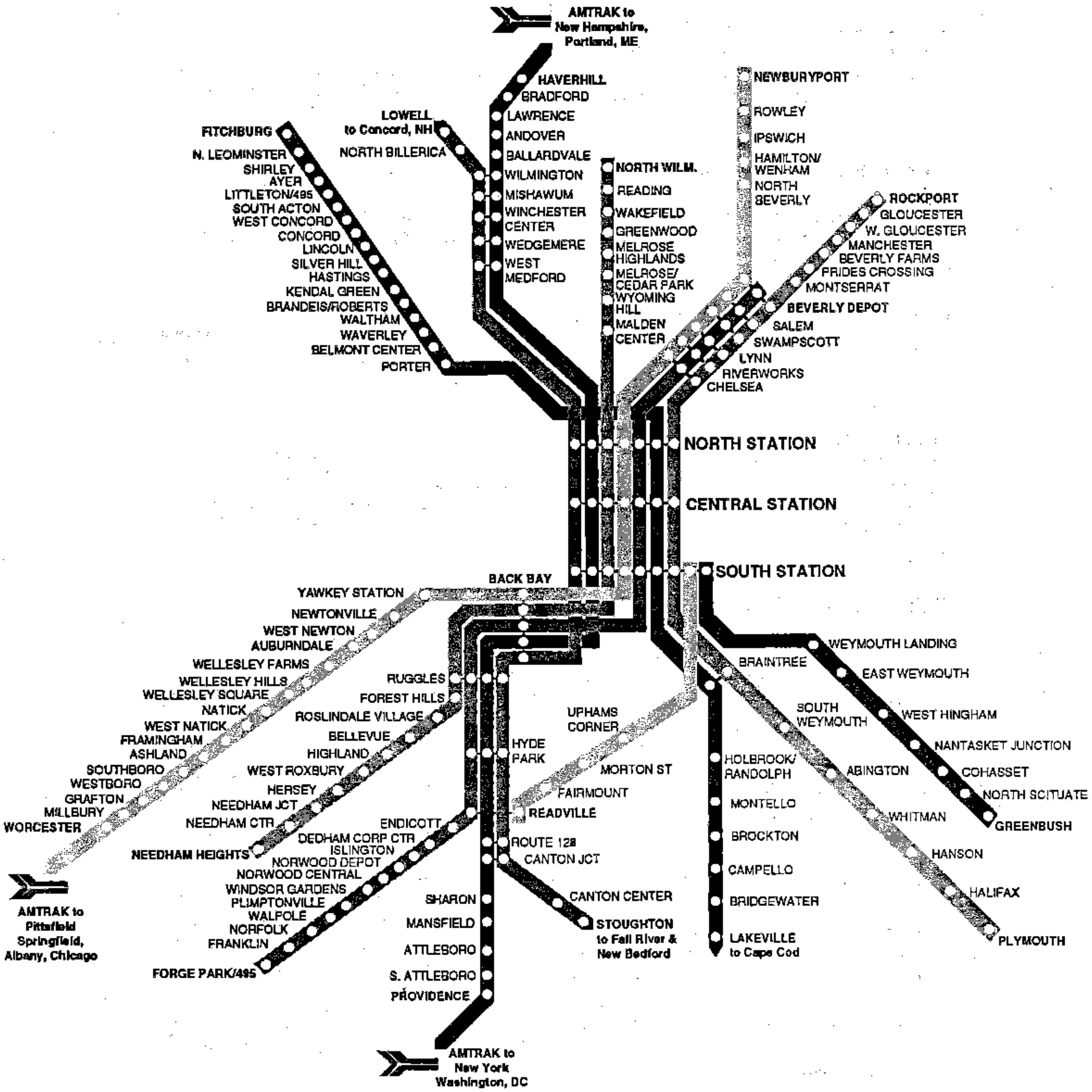
[33] Further study or operating experience may show the superiority of other potential rail pairings.

Figure G-39
Regional Rail Network Schematic



Source: Massachusetts Bay Transportation Authority

Gloucester and Rockport on Cape Ann. The two ends of this line would be complimentary in their length, running time, and market penetration relative to Boston highway access.

D Line: Beverly–Franklin

A Beverly–Franklin line would share approximately ten miles of right-of-way with the A and B lines between South Station and the southern Boston city limits. Combined with C and E line service, a level of service approaching that of rapid transit would be provided between Beverly and Boston.

E Line: Worcester–Newburyport

For the purposes of the Rail Link study, Framingham Line service extended to Worcester would be through-routed with Ipswich Line service, which would be extended to Newburyport. The E Line would operate in the same corridor as the C and D lines between South Station and Beverly.

F Line: Fitchburg–Middleborough

Two of the longest commuter rail lines are the Fitchburg and Middleborough services, which are both located in corridors with circuitous and congested highway access to Boston.

G Line: North Wilmington–Needham

Two of the shortest legs of the existing commuter rail service are the Reading and Needham services. Both services are characterized by close station spacing and a relatively dense network of supporting and alternative transit services. Linking these two short lines together would yield service with similar operating and ridership characteristics.

Fairmount and Greenbush Lines

Due to the fact that there are more routes to the south than to the north of Boston, and also because of practical limitations on the capacity of the Rail Link, the Fairmount and Greenbush services would continue to operate into and out of the present South Station.

Findings of the Task Force

The findings of the Rail Link Task Force can be summarized as follows:

- **Feasibility**. It is feasible to build a two track Rail Link in the Central Artery Corridor with expansion capacity to a total of four tracks. The only changes that would be required to the CA/T project would be that deeper supplemental earth support walls would need to be included to permit subsequent construction of the Rail Link. This could be done without affecting the schedule of the CA/T project.

- **Alignment/Stations** The Task Force's preferred alignment would start from two southerly tunnel portals, one along Herald Street east of Back Bay Station, the other in the vicinity of the railroad yards south of the West Fourth Street Bridge in South Boston. North of South Station the Rail Link would be located directly beneath the depressed Central Artery, before moving off to the westerly side of the Artery alignment and passing under the Charles River to north tunnel portals north of the Gilmore Bridge in Somerville. The Rail Link would have three stations, one under the existing South Station, the second near the MBTA Blue Line at State Street, and the third located between Haymarket and North Station.

- **Motive Power** Because of ventilation and safety requirements, all train operations through the Rail Link tunnel would need to be electrically powered.

- **Amtrak Service** The Rail Link would allow completion of the Northeast Corridor Amtrak intercity rail system with provision of through-routed service from Portland, Maine to Boston, New York, and Washington, D.C. This rail link would also allow for future provision of rail service to New Hampshire.

- **Regional Rail Service** The Rail Link would create a unified rail system for metropolitan Boston by combining the two currently separate northside and southside commuter railroad services. This would provide both improved core area trip distribution and regionwide service interconnectivity.

- **Regional Rail Ridership** With the Rail Link and faster electrified regional rail service, ridership would increase by 57,000 trips per weekday. Of the additional daily railroad trips, approximately 23,000 will be diverted from the highway system. Most of the remainder will be diverted rapid transit trips.

- **South Station Capacity** Construction of the Rail Link would eliminate projected South Station capacity problems. Old Colony service planned for 1996 and electric Metroliner service scheduled for 1998 will raise South Station track needs to sixteen—three above the thirteen that will be available when current track additions are completed. Additional commuter rail expansion would increase needs. Building the Rail Link would provide adequate railroad station capacity in downtown Boston into the indefinite future.

- **Construction Costs** Capital costs of $1.85 billion would be anticipated for Phase I of the Rail Link project. Of this total, $1.3 billion would be for construction of the Rail Link tunnel and stations, and installation of two tracks within the four-track tunnel. The other $550 million would be required for electrification of the lines to Haverhill, Lowell and Stoughton, and for the associated electric motive power. (The Providence line will be electrified as part of Amtrak's Northeast Corridor Project.)

  Phase 2 would cost an additional $1.78 billion. This would include $1.4 billion for electrification and locomotives for the remaining routes, and $417 million to complete four track installation within the tunnel.

- **Project Timing** Because of the time necessary for environmental analyses, project engineering, and resolution of institutional issues, it is not feasible to begin Rail Link construction in 1993 concurrent with that of the depressed Central Artery. Building Artery project slurry walls that extend down to the full depth necessary for both Artery and Rail Link construction, however, will make it possible for Rail Link construction to begin later than Artery construction.

Ridership

Between now and the year 2010, it is projected that commuter rail ridership will increase by 50,000 trips per weekday to 120,000 trips per weekday. This large increase will be the result of the following:

- Restoration of Old Colony service.
- Commuter rail service extensions to Worcester and Newburyport.
- Land use projections anticipating a growth of 30% in employment to the year 2010 for the area in and near downtown Boston.
- Regional housing growth in "bedroom suburbs" that would be better served by commuter rail to downtown Boston than by competing modes.

With the Rail Link lines, and electrified service on all lines, commuter rail ridership would increase by up to 57,000 additional trips per weekday (see Table G-65). Of these 57,000 rides, approximately 23,000 would be new transit trips diverted from automobiles. Most of the remaining 34,000 trips would be made by travelers that had been using rapid transit.[34] At these ridership levels, the Rail Link would generate more new transit ridership than any other PMT project except the full Inner Circumferential rail line from Logan Airport to JFK/UMass Station.

Table G-65
Ridership Impacts of the North Station - South Station Rail Link

	Total New Trips	New Transit Trips
North Station - South Station Rail Link	57,000	23,000

Boardings and alightings at downtown stations would increase by 67,000 trips per weekday (see Table G-66). North Station passengers would increase from 29,000 to 33,000, and the new Central Station would be used by 30,000 passengers—nearly as many as North Station. South Station would be, by far, the most heavily used station, with an increase of 28,000 weekday trips to 82,000. Back Bay usage would grow modestly from 19,000 to 24,000 trips per weekday. The largest increases would occur at Central and South stations because these stations would be the most convenient to most passengers' ultimate destinations.

Because more riders could travel by commuter rail to points near their final destinations, many of the commuter rail/rapid transit transfers that now take place would no longer be necessary. The largest drop in transfers would be with the Orange Line at North Station. At the same time, the Rail Link would also result in new commuter rail to rapid transit transfers. New direct transfers to the Red and Blue Lines would be available to northside riders, and new direct connections to the Green and Blue Lines would be available to southside riders. A large number of new transfers would also be expected to and from the South Boston Piers Transitway: 25,200 with the Rail Link versus 11,900 without the Rail Link.

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[34] It should be noted that intercity passengers using Amtrak trains are not included in these figures. Amtrak ridership forecasts are being prepared by the Federal Transit Administration in support of the Rail Link planning effort. Amtrak ridership is concentrated at South Station, and current planning assumes that South Station and Back Bay Station will continue as the Amtrak stations in Boston. While Amtrak ridership is small in relation to regional rail, the percent increase in Amtrak patronage resulting from the Rail Link is expected to be significant.

Table G-66
Projected Commuter Rail Ridership at Downtown Boston Stations

	Total Trips	Increase
North Station	33,000	4,000
Central Station	30,000	30,000
South Station	82,000	28,000
Back Bay	24,000	5,000

Costs and Cost-Effectiveness

The regional rail service concept structured around the Rail Link would be implemented in two phases. Phase 1 would include completion of a two-track Rail Link, with implementation of through intercity service between New York and Portland, and of electrified regional rail service between Providence and Haverhill, and between Stoughton and Lowell (see Figure G-39). Phase 1 is anticipated to have a total cost of $1.85 billion. Of this total, $1.3 billion would be for the Rail Link and stations and the remaining $550 million would be for electrification and electric locomotives.

Phase 2 would involve expanding the Rail Link tunnel to four tracks and electrifying the remainder of the commuter rail system. This would be necessary to provide the through-routing of all of the northside and southside lines described above. Phase 2 would cost an additional $1.78 billion. Of the Phase 2 expenditures, the greatest portion would be invested in electrification and locomotives ($1.4 billion). The expansion of the Rail Link to four tracks would cost approximately $417 million.

The total capital cost of the two phases would be $3.63 billion. This cost makes the Rail Link the single most expensive project examined in the PMT. However, because of the inter-regional significance of the Rail Link (in terms of Amtrak service), it is possible that special federal funding could be available for the Rail Link that would not be available for other transit projects.

The $3.6 billion total capital cost translates to $64,000 of capital investment per new regional rail trip and $158,000 per new transit trip. Of the PMT projects that would significantly increase ridership, these capital costs per new rider for the Rail Link are the highest. (As mentioned before, these figures do not include new Amtrak riders attracted to through-routed intercity service.)

Table G-67
Cost-Effectiveness of the Rail Link

	Operating Cost (Annual)	Fare Revenue (Annual)	Capital Cost	Capital Cost/ New Trip
North Station - South Station Rail Link				
Phase 1	NA	NA	$1,850m	NA
Phase 2	NA	NA	$1,780m	NA
Total	$47m	$36m	$3,630m	$158,000

The Rail Link would make commuter rail operations more efficient by eliminating downtown layovers. This, together with the reduced travel times of electrified operations, would mean that more service could be provided with a given amount of equipment and crew. Including the impact of these efficiencies, the additional service that would be provided with the Rail Link would increase annual operating costs by $47 million.

The new trips attracted by the Rail Link and the improved service that would be operated would increase annual revenue by $36 million. This would represent a farebox ratio of 77 percent, which would be very high for a project of this magnitude.

Air Quality Benefits

The Rail Link would provide the greatest improvement in air quality of any of the PMT projects. With both Phase 1 and Phase 2 improvements, the additional trips attracted to commuter rail would reduce regional VMT by 366,000 miles per weekday. This would result in a 0.54 percent reduction in regional emissions.[35] By comparison, the project with the second highest air quality—the full inner circumferential LRT alignment—would reduce regional emissions by 0.22 percent. Most PMT projects would reduce regional emissions by less than 0.10 percent.

However, because the cost of the full project is high, the cost of achieving the air quality benefits would also be high, at $8.1 million per kilogram of VOC eliminated per weekday. Of projects that would generate significant ridership increases, this cost would be exceeded only for a Blue Line extension to Riverside (up to $14.2 million).

Table G-68
Air Quality Impacts of the Rail Link

	% Reduction Regional Emissions	Capital Cost/kg of VOC Elim/weekday
North Station - South Station Rail Link	0.54%	$8,136,000

Conclusions

The Central Artery Rail Link would provide a number of new transportation options to the residents and travelers in eastern Massachusetts and the Northeast by providing better connections combined with a higher level of rail service. It would divert 23,000 trips per weekday from automobiles to MBTA commuter rail services. This is the second-highest number of auto-to-transit diversions for any individual project included in the PMT.

The Rail Link would provide a significant reduction in regional emissions, of 0.54 percent. This is the highest of any project, and three times that of a full inner circumferential LRT line, which would provide the second-greatest improvement.

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[35] This reduction is due only to the diversion of automobile trips to commuter rail. There would be additional air quality benefits due the use of electric locomotives instead of diesel locomotives. The North-South Rail Link report estimates that the elimination of diesel locomotives would increase the reduction in regional emissions to 1.26 percent.

While the ridership and air quality benefits would be high, costs would be very high. The cost to construct the Rail Link and to electrify the existing system would be approximately $3.6 billion. This represents a cost of $158,000 per new transit trip, and $8.1 million per kilogram of VOC per weekday. The $158,000 capital cost per new transit trip is the highest of any PMT project that could generate significant new ridership, and the $8.2 million cost per kilogram of VOC eliminated is the second highest.

Because of the high cost of the project, funding would be a major issue—both in terms of availability and the possible impact on other projects. However, due to the inter-regional significance of the Rail Link and the opportunities for expanded Amtrak service, it is possible that special federal funding may be available for this project that would not be available for competing projects.

Based on the findings of the Rail Link Task Force, it is clear that the Rail Link would provide a number of benefits to the region and the Northeast. Additional information on a Rail Link should soon be available following the completion of the FTA's study. In the short-term, based on the potential benefits of the Rail Link, the new Central Artery should be designed with provisions for the supplemental excavation support walls that would allow future construction of the Rail Link in the Central Artery alignment. A decision on whether to construct the Central Artery Rail Link should be deferred until after funding issues have been addressed and the FTA study has been completed. Further study to resolve outstanding issues is recommended.

Improved Connections to Logan Airport

This section summarizes the results of the PMT analysis of providing new connections to Logan Airport. These include:

- Bus Service from North Station
- Bus Service from South Station
- Blue Line Spur to Logan Central Terminal
- Express Bus from Newton Corner
- Express Bus from Waltham (Route 128 at Winter Street)

Existing Conditions

Currently a number of public transportation options are available for travel to and from Logan Airport by air travelers or airport employees:

(1) The MBTA's Blue Line runs from Wonderland Station in Revere to Bowdoin Station in Downtown Boston, touching the edge of Logan Airport in East Boston. Free shuttle buses operated by Massport connect the Blue Line Airport Station with all Logan terminals.

(2) Three Logan Express bus routes from suburban parking lots to the airport are operated under Massport contracts. The outer endpoints are the Shoppers World mall in Framingham, Forbes Road in Braintree (near the southern intersection of I-93 and Route 128), and a lot adjacent to Mishawum Station in North Woburn (near the northern intersection of I-93 and Route 128).

(3) The Logan water shuttle runs from Rowe's Wharf on the edge of the Boston Financial District to a dock on airport property. A shuttle bus carries passengers from the airport dock to the Logan terminals.

(4) Numerous private operators provide scheduled and demand-responsive bus, van, and limousine services to points throughout New England.

The Blue Line is the least expensive way to reach the airport, but it is inconvenient for many travelers. To reach the airport via this route, Red Line passengers must transfer three times and commuter rail passengers must transfer three or four times. All MBTA passengers arriving at the Blue Line Airport station are faced with an escalator or stairs and then a trip on a shuttle bus; heavy luggage serves as a strong disincentive to use rapid transit when faced with these obstacles.

Logan Express buses offer no-transfer trips directly to the airline terminals. The fare ($7.00 on each route) is greater than those of existing rapid transit or commuter rail/rapid transit alternatives to the airport from similar distances, and the buses are subject to traffic delays, especially on the Central Artery and in the Callahan Tunnel. Nevertheless, the Logan Express routes are significantly more convenient than other transit options for many airport passengers.

The water shuttle offers a good alternative for passengers departing from the Waterfront or the Financial District. For less than the price of taxi fare, the water shuttle offers a fast, reliable ride across the harbor. For passengers from other origins, however, transfers to the water shuttle are even more inconvenient than those to the Blue Line.

Most of the private bus, van and limousine services are intended either to serve points far outside of the MBTA District, or to transport business travelers and tourists between the airport and hotels. Generally, they do not serve airport travel needs of Metropolitan Boston residents.

PMT Alternatives

Potential new services would be designed to complement and improve upon those identified above. The PMT examined five possible expansions of service.

Bus Service from North Station

This project would provide high-frequency bus service between North Station and the passenger terminals at Logan Airport. Buses would operate through the Callahan and Sumner tunnels. For Green and Orange Line passengers, transfers would be reduced from two to one, and for northside commuter rail passengers, from three to one.

The service levels assumed in the PMT analysis were every 15 minutes during peak periods and every 30 minutes during off-peak periods. It was generally assumed that travel time through the tunnels would be shorter and more reliable after the opening of the Third Harbor Tunnel.

Bus Service from South Station

This project would institute shuttle bus service between South Station and the passenger terminals at Logan Airport.[36] Buses would utilize the new harbor tunnel. The bus route would provide direct service and reduce the number of transfers for Red Line passengers from three to one and for southside commuter rail passengers from three or four to one.

The service frequency assumed in the PMT analysis was 15 minutes during peak periods and 30 minutes during off-peak periods. Buses would have head-of-queue privileges through the Third Harbor Tunnel, allowing for short, reliable travel times.

Blue Line Spur to Logan Central Terminal

Blue Line service to the planned Central Terminal would entail a spur track from Maverick Station to the vicinity of the current Central Parking Garage. Existing service to Airport Station and the Massport-provided shuttle bus between Airport Station and the Logan terminals would be discontinued. A new shuttle service designed to serve inbound Blue Line riders between Wonderland and Wood Island would be instituted from Wood Island to all Logan terminals. This service would be free of charge.

The Blue Line spur would eliminate the transfer at Airport Station to the Massport shuttle service, providing a one-vehicle ride from Downtown Boston to Logan Airport.

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[36] Massport ran such a "Logan Link" service from South Station to Logan experimentally from 1992 until July 1, 1993. It was discontinued because of low ridership.

Headways would be 4 minutes during peak periods to both Wonderland and Logan Central Terminal, and 8 to 11 minutes during off-peak periods.

Express Bus Service from Newton Corner

This service would provide MetroWest residents a direct one-seat ride to Logan Airport via the Massachusetts Turnpike. The one-way fare would be $7.00. This service would expand on existing Massport "Logan Express" services from Braintree, Framingham and Woburn.

Frequencies would be the same as other Logan Express services: 30 minutes during the AM/PM peak and mid-day periods, and 60 minutes in the evening and on weekends.

Express Bus Service from Waltham (Route 128 at Winter Street)

This service would provide northern MetroWest residents a direct one-seat ride to Logan Airport via Route 128 and the Massachusetts Turnpike. The one-way fare would be $7.00. This service would expand on existing Massport "Logan Express" services from Braintree, Framingham and Woburn.

Service levels would be the same as other Logan Express services: 30 minutes during the AM/PM peak and mid-day periods, and 60 minutes in the evening and on weekends.

Ridership Impacts

The five alternatives would vary in performance (see Table G-69). Model results indicate that the bus service from North and South Station would have moderate ridership, but the great majority of those riders would be diverted from other transit services; only 90 of the weekday riders on the North Station route, and 45 of the riders on the South Station route would be drawn from automobiles. The two new Logan Express routes would do somewhat better in encouraging new transit trips, with 124 each, but would have lower total ridership. The Blue Line spur would have a much greater impact on transit system ridership, diverting 2,000 weekday trips from automobiles.

Table G-69
Ridership Impacts of New Connections to Logan Airport

	Total Trips	New Transit Trips
North Station Bus	718	90
South Station Bus	1,413	45
Blue Line Spur	7,232	2,000
Express Bus from Newton Corner	271	124
Express Bus from Waltham	192	124

Ridership projections for the bus routes are among the lowest for all projects examined in the PMT, especially with regard to new transit trips. Likewise, a Blue Line spur would carry fewer total and new transit riders than most of the other rapid transit and light rail projects examined.

Travel time savings for the four bus routes would be among the lowest of all PMT projects examined. However, the travel time savings for the Blue Line spur would be near the top of the middle range among the rapid transit and commuter rail projects. The elimination of the airport shuttle bus transfer would yield significant time savings for rapid transit passengers.

Costs and Cost-Effectiveness

All four of the bus routes would be inexpensive to implement and to operate (see Table G-70). Capital costs for the four routes would range from $0.8 to $1.4 million. The capital costs per new transit rider would be relatively high for bus routes, ranging from $6,700 for the Newton Corner route to $30,400 for the South Station route.

The Blue Line spur would have much higher capital costs, estimated at $29.4 million. This figure is the lowest among the proposed rapid transit projects in the PMT. Because of the high number of new riders (relative to the bus routes to Logan), the capital cost per new weekday rider would be relatively low, at $14,700. This is the lowest such cost for all rapid transit projects studied in the PMT.

The four bus routes would increase operating costs by $0.38 to $0.58 million per year, and very little of these costs would be offset by new fare revenue. Resulting farebox return ratios would be low on all four routes: below 10% in each case.

The operating cost for the Blue Line spur would be just over $1 million annually. The fare revenue from the project is estimated at $355,000, yielding a 34.1 percent farebox return ratio. This ratio is close to the average of the existing rapid transit system.

Table G-70
Cost-Effectiveness of New Connections to Logan Airport

	Operating Cost (Annual)	Fare Revenue (Annual)	Capital Cost[37]	Capital Cost per New Trip
North Station Bus	$0.4m	$0.01m	$1.1m	$12,200
South Station Bus	$0.5m	$0.006m	$1.4m	$30,400
Blue Line Spur	$1.0m	$0.3m	$29.4m	$14,700
Express Bus from Newton Corner	$0.4m	$0.04m	$0.8m	$6,700
Express Bus from Waltham	$0.6m	$0.05m	$1.1m	$8,850

Air Quality Impacts

Each of the four bus routes would have a negligible effect on regional emissions. The North and South Station buses would attract so few new riders to the transit system that the effect on air quality would be essentially zero. The new Logan Express bus routes would each cause a reduction of less than 0.002%. The Blue Line spur would have a somewhat larger effect, reducing emissions by 0.02%. This reduction would be small relative to the other

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[37] Costs do not include land acquisition.

Table G-71
Air Quality Impacts of New Connections to Logan Airport

	% Reduction Regional Emissions	Capital Cost/kg of VOC Elim/weekday
North Station Bus	≈0	NA
South Station Bus	≈0	NA
Blue Line Spur	0.02%	$1,771,808
Express Bus from Newton Corner	0.002%	$656,850
Express Bus from Waltham	0.002%	$663,112

rapid transit projects in the PMT, but the capital cost per kilogram of VOC eliminated each weekday would be lower than those of every other rapid transit project except the Green Line to Medford Hillside. The air quality improvement costs for the bus routes would be relatively low compared to all PMT projects, but high compared to the other bus routes studied.

Conclusions

Of the new connections to Logan Airport studied in the PMT, only a Blue Line spur to the Central Terminal would have a large effect on transit ridership. It would also be the costliest of the connections by far. The bus routes from North and South Station are predicted to have negligible effects on transit ridership. To some extent, this may reflect limitations of the demand model in predicting mode choices for airport access, but recent experience with bus service from South Station to Logan suggests that the projections are reasonable.

The new Logan Express routes would perform somewhat better than the North and South Station routes in new transit ridership, but would carry fewer total riders. Massport's experience with its present express routes indicates that the new routes, especially the Waltham route, would not have enough riders to justify their operation.

Whether the Blue Line spur would cause a significant increase in the use of rapid transit for access to the airport is also unclear. It is difficult for the demand model to account for such factors as having to climb stairs with luggage, and the consequences of missed flights. An alternative plan for the reconstruction of Airport station in its present location, with cross-platform transfers to the shuttle bus, may achieve a similar improvement in convenience to the Blue Line spur, at a lower cost.

Clearly, some improvement in access from the Blue Line is desirable. Further study by Massport of rapid transit connections to the airport should continue as part of the ongoing Logan improvement program.

Blue Line Extension to Lynn

Existing Conditions

The Blue Line currently runs from Wonderland Station in Revere to Bowdoin Station in the Government Center area of downtown Boston. At six miles, it is the shortest of the MBTA's three high-platform rapid transit lines. The Blue Line has direct connections with the Orange and Green Lines, but not with the Red Line. Headways are currently 3.5 minutes during peak periods.

The Rockport/Ipswich commuter rail line runs from North Station through Chelsea into Lynn and then beyond to other North Shore communities. In Revere, the commuter rail tracks run within about one third of a mile of Wonderland Station. Past proposals for extending the Blue Line have always involved use of the commuter rail right of way from some point north of Wonderland.

Four MBTA express bus routes (426, 441/442, 450, and 455) provide through service between points in Lynn and Haymarket Square in Boston.[38] Three of these operate through Central Square, at the heart of downtown Lynn. This is also the location of the Lynn commuter rail station. Peak-period commuter rail headways at Lynn Station range between 20 and 30 minutes. Each express bus route serving Central Square has peak headways of ten to 20 minutes. The MBTA recently completed construction of a large parking garage at Central Square for commuter rail line and express bus passengers. This project included new commuter rail platforms.

PMT Alternative

The PMT examined a four-mile extension of the Blue Line from its current terminus at Wonderland to Central Square in Lynn (see Figure G-40). The extension would use an abandoned narrow-gauge railroad right-of-way from Wonderland to West Lynn, and then continue to Central Square beside the Rockport/Ipswich commuter rail line. Intermediate stations would be located at Point of Pines, serving a residential community in northern Revere, and at West Lynn, serving the General Electric complex and other employment centers there.

Previous studies of a Blue Line extension to Lynn have assumed a somewhat different routing, joining the Rockport/Ipswich right of way just north of Wonderland and following it all the way to Central Square. Although such a scheme would involve less land-taking, it would require widening the existing rail grade through the environmentally sensitive Saugus Marshes. Therefore, the narrow gauge route to West Lynn was chosen for study in the PMT. A separate consultant study of several North Shore transit improvements is considering both possible alignments. Ridership figures for the two alignments should be similar. The only station not served by both routes would be Point of Pines, where the PMT analysis predicts very low ridership.

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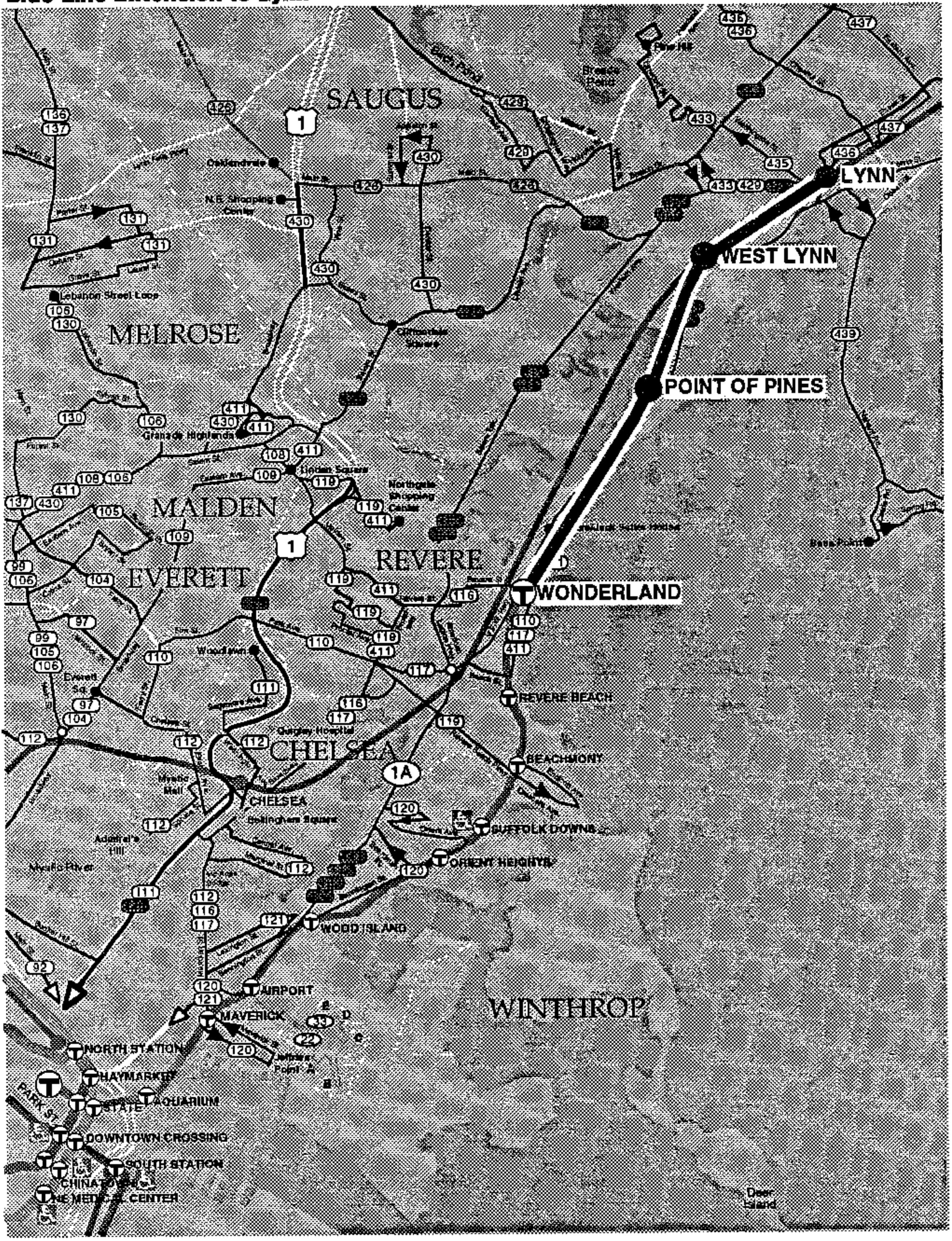
[38] Despite their classification as express bus routes, all four make many stops between downtown Lynn and Boston, and only Route 426 operates for a substantial part of its length on limited-access highways.

Figure G-40
Blue Line Extension to Lynn



Ridership Impacts

The PMT demand forecasts for the year 2020 indicate that the Blue Line extension to Lynn would serve 11,340 weekday riders, of which 4,860 would be new users of the transit system. The rest would be drawn from other transit services such as commuter rail and express bus, or diverted from existing Blue Line stations.

On a station-by-station basis, weekday ridership would be as follows:

Central Square Lynn:	7,140
West Lynn:	4,120
Point of Pines:	80
Total	11,340

At these ridership levels, the Central Square Station would serve more riders than six of the 12 existing Blue Line stations now serve, but West Lynn would rank below all Blue Line stations except Suffolk Downs and Wood Island. The projected ridership for a Point of Pines Station is far below that of any existing MBTA rapid transit station. Consequently, the final design of a Lynn extension would probably omit Point of Pines.

Travel time savings for existing transit riders would be 893 hours per weekday or 273,258 per year. These figures are relatively low among the rapid transit extensions, because the Blue Line would not offer an in-vehicle travel time advantage over commuter rail. The trip from Lynn to Downtown Boston on the commuter rail line currently takes 26 minutes, compared to a projected 30-minute Blue Line trip to Government Center. Blue Line trains would stop 12 times between Lynn and Government Center, compared to the one or two stops now made by commuter rail trains between Lynn and North Station.

The Blue Line would have the advantage of much greater service frequency, resulting in shorter average wait times. Blue Line stations in downtown Boston are more centrally located than either North Station or the Haymarket terminal used by North Shore express buses, so the Blue Line would have lower average access times. For Logan Airport employees and passengers, the Blue Line also has the advantage of providing direct service to Airport Station.

Costs and Cost-Effectiveness

The construction cost of the Blue Line to Lynn would be in the mid-range of PMT projects examined to date (see Table G-72). The initial capital cost would be $275 million for track and power, three stations, a new bridge over the Pines River and 100 Blue Line vehicles. The capital cost per new transit rider would be higher than any other rapid transit or commuter rail extension included in the SIP and CA/T Mitigation and Additional Expansion categories, at $56,600.

It would also be among the more expensive PMT projects in annual operating cost, at $10.25 million. Fare revenue from the extension would be $1.4 million annually (assuming that riders at stations beyond Wonderland would pay the same fare as Red Line riders from Quincy—double fare in, single fare out), resulting in a farebox recovery ratio of only 14 percent. The operating subsidy per passenger would also be fairly high, at $2.54. Because of the relatively low travel time savings, the cost per passenger hour saved would be high, at $75.46.

Table G-72
Costs and Revenues of Blue Line Extension to Lynn

Operating Cost (Annual)	Fare Revenue (Annual)	Capital Cost	Capital Cost/ New Trip
$10.25m	$1.4m	$275m	$56,600

Air Quality Impacts

The Blue Line extension to Lynn would reduce regional emissions by 0.07 percent, which would be a moderate reduction. The air quality improvements would be among the more expensive to attain among all PMT projects. The capital cost per weekday kilogram of VOC eliminated would be $4.6 million. This is more expensive than any of the commuter rail extensions and the other rapid transit extensions included in the recommended program.

Conclusions

There is merit to the idea of bringing high frequency transit service to densely developed Lynn. The Blue Line extension could be an economic benefit for Lynn, and it would provide a higher level of service for commuters to the urban core. There is strong support for such an extension from the City of Lynn and other North Shore communities.

These improvements in service would come at a high cost, however. By most measures, the Blue Line extension is one of the more costly, and least cost-effective projects. When North Shore transit improvements were studied in the 1970s, the MBTA decided to invest in improvements to the commuter rail service rather than extending the Blue Line (although it did not rule out the latter). Higher frequency, higher speed commuter rail service could offer many of the benefits of the Blue Line at a much lower cost.

The consultant study taking place concurrently with the PMT will provide additional information about a Blue Line extension to Lynn as well several other options for improved North Shore transit, including conversion of the Rockport and Ipswich lines to electrified light rail or rapid transit, enhanced commuter rail service, and enhanced express bus service.

Green Line Extension to Medford Hillside, Red Line – Blue Line Connector Blue Line Extension to Medford Hillside

The Red and Blue Lines are currently the only two rapid transit lines in the MBTA system without a direct connection. The 1977 PMT examined a Red Line-Blue Line connector only as a stand-alone project. In the current PMT process, a Red-Blue connector has been examined both by itself and as a part of longer Blue Line extensions to Riverside Station or to Medford Hillside. A Blue Line extension to Riverside would essentially supplement or replace several sections of the existing Green Line system. Three alternatives for such an extension are discussed in a separate section of Appendix G.

A Medford Hillside extension would serve Somerville, a densely developed city with a lower level of direct transit service to downtown Boston than comparable areas. Another alternative for the same purpose would be to extend the Green Line from Lechmere Station to Medford Hillside. This section discusses the following three alternatives:

1. An extension of the Green Line from Lechmere to Medford Hillside.

2. An extension of the Blue Line from Bowdoin Station to Charles Station on the Red Line.

3. An extension of the Blue Line to Medford Hillside via Charles Station

Alternatives 1 and 2 could be built either together or separately. Alternative 3 would include the extension in Alternative 2, and would be mutually exclusive with Alternative 1.

Existing Service

The Blue Line currently runs from Wonderland Station in Revere to Bowdoin Station in the Government Center area of downtown Boston. At six miles, it is the shortest of the MBTA's three high-platform rapid transit lines. It is also the only one of the three terminating in the Boston Central Business District instead of running through between termini on opposite sides. The Blue Line has direct connections with the Orange and Green Lines, but not with the Red Line.

The Green Line Central Subway consists of a light rail tunnel in Boston from west of Kenmore Square to north of Haymarket Square, with a branch from west of Symphony Station to Copley Square, and an elevated line from near Haymarket to Lechmere Square in East Cambridge. All service in the Central Subway is currently provided by trains originating at points on three surface routes (the B, C, and D lines) west of Kenmore, and one (the E Line) west of Symphony. In the Central Subway, B and D Line trains are scheduled to terminate at Government Center Station, C Line trains at North Station, and E Line trains at Lechmere. (Terminal assignments are revised from time to time as demand and operating requirements dictate.) Only trains going to Lechmere run through between opposite sides of the Boston CBD, and Lechmere is less than half a mile from the CBD border.[39]

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[39] Neither Lechmere nor Bowdoin was originally designed or operated as a terminal station. Streetcar service originally continued beyond Lechmere via surface tracks to Clarendon Hill in Somerville and to Harvard Square. The segment of the Blue Line between Maverick

Green Line Extension from Lechmere to Medford Hillside

This project would extend the Green Line from Lechmere Station 3.9 miles to Medford Hillside (Winthrop Street) in Medford (see Figure G-41). The first mile of this extension from Lechmere to Mystic Junction would use the old Boston & Lowell Railroad Main Line right of way, currently used only for freight service operated by the Springfield Terminal Railway Company. The balance of the extension would share the right of way of the Lowell commuter rail line. This segment is owned by the MBTA.

There would be stations at Washington, School, and Lowell Streets in Somerville, at Ball Square (Broadway) on the Somerville/Medford border and at Medford Hillside. The School Street and Lowell Street Stations would each include 50 parking spaces. The Medford Hillside Station would have 200 spaces.

Service would be provided by extending one of the four surface Green Line routes through from its present inner terminal to Medford Hillside. Trains would run every six minutes in peak periods and every 12 minutes at other times. The running time from Medford Hillside to Lechmere would be 10.5 minutes. This would result in a total travel time of about 18 minutes from Medford Hillside to Government Center. For passengers that now ride MBTA buses to Lechmere from points in the extension corridor and transfer to the Green Line, travel time savings would range up to 17 minutes each way.

Red - Blue Connector
(Blue Line Extension from Bowdoin Station to Charles Station)

This project would consist of an extension of the Blue Line from its present inner terminal at Bowdoin Square via a subway under Cambridge Street to Charles Station on the Red Line. There would be no intermediate stations. This extension would provide a direct transfer connection between the Red and Blue Lines for the first time. (At present, the Red and Blue Lines both make direct connections with the Orange and Green Lines, and the latter two connect with each other; only a Blue Line - Red Line connection requires two transfers.). A direct Blue Line - Red Line connection would provide better distribution for trips starting on both lines, including improved travel to Logan Airport.

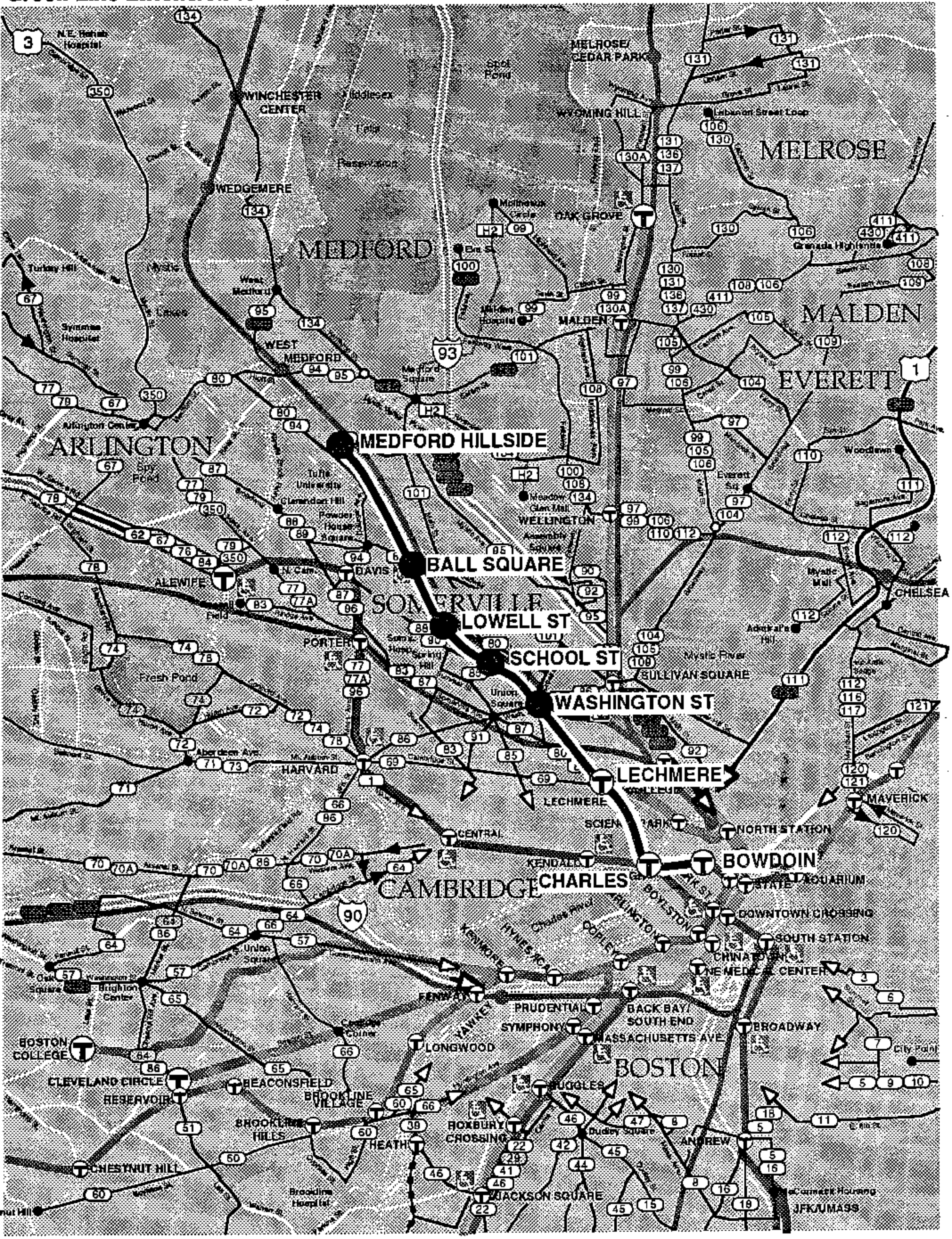
The running time from Charles to Bowdoin would be 1.3 minutes. From Charles to Government Center, the running time would be 2.5 minutes.[40] All Blue Line trains would be extended through to Charles Station. Present Blue Line headways are 3.5 minutes peak, six minutes mid-day and early evening, and 12 minutes late evening.

The lack of a direct connection between the Red and Blue Lines is more of a barrier to travel in terms of the perceived inconvenience of transferring twice than in actual travel time.

Square and Bowdoin was also originally a streetcar tunnel serving several routes. Service included run-throughs from East Boston to Harvard Square using surface tracks west Bowdoin. Through service beyond Lechmere and Bowdoin was discontinued in the early 1920s, in attempts to reduce congestion and increase service reliability within the respective tunnels.

[40] Under current MBTA plans, Bowdoin Station may be abandoned. In that case, the running time from Charles to Government Center would drop to about two minutes.

Figure G-41
Green Line Extension to Medford Hillside



During peak hours, a direct Blue-Red connection at Charles Street would reduce travel times between Blue Line stations east of State and Red Line stations north of Charles by an average of 1.2 minutes compared to a double transfer via the Green Line. Because of the longer travel distance, trip times from Blue Line stations east of State to Red Line stations south of Downtown Crossing would increase by an average of 2.8 minutes compared to a double transfer via the Orange Line.

Blue Line Extension from Bowdoin to Medford Hillside

The first segment of the extension would be the same as the Bowdoin-Charles connector described in Alternative 2. From Charles Station, the Medford Hillside extension would continue in a tunnel under the Charles River to Lechmere Station. From there, the alignment and station locations would be the same as those of the Green Line extension to Medford Hillside described in Alternative 1 (see Figure G-42).

Ridership Impacts

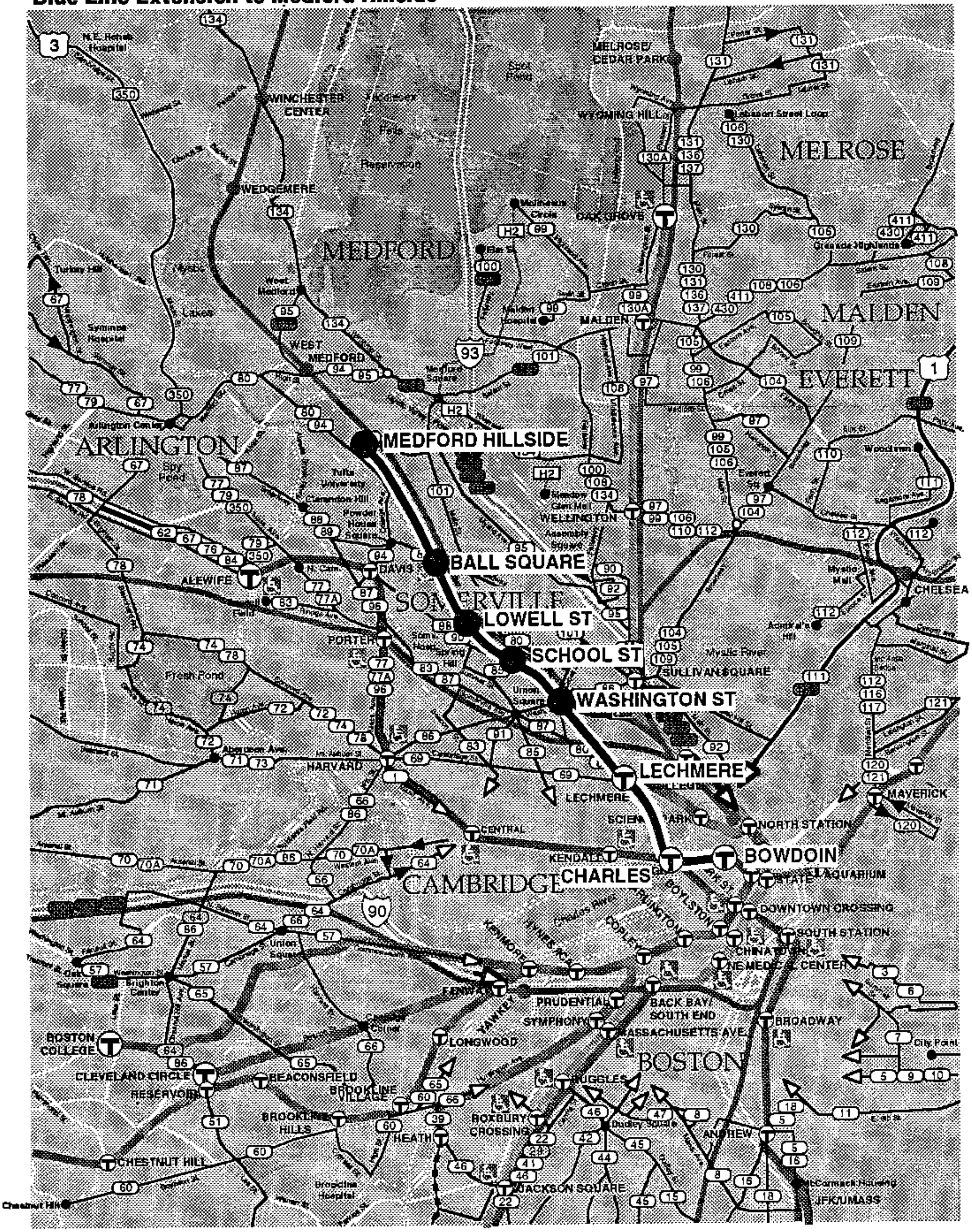
A Green Line extension from Lechmere to Medford Hillside would serve an estimated 11,560 riders a day. Of these, 3,660 would be new transit users, and 7,900 would be diverted from other MBTA services—primarily Somerville bus routes. A Blue Line extension from Bowdoin all the way to Medford Hillside would attract an estimated 32,870 new riders to the Blue Line, including 7,283 new transit riders. A Red-Blue Connector alone would carry 19,210 total riders and 4,970 new transit trips per weekday (see Table G-73).

Table G-73
Ridership Impacts of Blue/Green Line Extensions

	Total Trips	New Transit Trips
Green Line to Medford Hillside	11,560	3,660
Red-Blue Connector	19,210	4,970
Blue Line to Medford Hillside		
Bowdoin to Charles Segment	19,210	4,970
Charles to Medford Hillside Segment	13,660	2,310
Total	32,870	7,280

A number of conclusions can be drawn from these projections. First, 58 percent of the total ridership and 68 percent of the new transit ridership on a Blue Line extension to Medford Hillside would be on the Red - Blue Connector segment. The extension beyond Charles would attract a similar number of riders as the Green Line extension to Medford Hillside: more total riders (13,660 versus 11,560) but fewer new transit riders (2,310 versus 3,660). The Green Line extension would attract more new transit riders because it would provide direct service to much more of downtown Boston (including Park Square, the Back Bay, and the Fenway) than a Blue Line extension. The higher total ridership for a Blue Line extension would be mostly the result of diversions from the Green Line to the Blue Line at Lechmere Station. Lechmere riders are not included in the total for the Green Line extension, since a Green Line Lechmere Station is part of the base-case network.

Figure G-42
Blue Line Extension to Medford Hillside



Of the various combinations of these projects, new transit ridership would be maximized by the construction of the Red Line - Blue Line Connector in conjunction with a Green Line extension to Medford Hillside, rather than with a Blue Line extension through Somerville (8,630 new transit trips versus 7,280). As further discussed below, this combination would also be far less expensive than the construction of a Blue Line extension to Medford Hillside.

Costs and Cost-Effectiveness

The estimated capital cost of a Green Line Medford Hillside extension is $88 million. Capital costs for the Blue Line extensions would be $138 million to Charles only, and $549 million to Medford Hillside (see Table G-74). The Charles-Medford Hillside segment alone would cost $411 million, or $323 million more than a Green Line extension to Medford Hillside.

Table G-74
Cost-Effectiveness of Blue/Green Line Extensions

	Operating Cost (Annual)	Fare Revenue (Annual)	Capital Cost[41]	Capital Cost/ New Trip
Green Line to Medford Hillside	$2.1m	$1.1m	$88.0m	$24,000
Red-Blue Connector	$0.5m	$1.5m	$137.5m	$27,700
Blue Line to Medford Hillside	$10.9m	$2.1m	$548.4m	$75,300

The largest component ($140 million) of the difference in cost between the Blue and Green Line extensions is the additional 0.8 mile length of the Blue Line extension, all of which would be in a tunnel under the Charles River. Another $55.5 million is attributable to the purchase of 50 new Blue Line cars for the extension, compared to only 10 new LRVs for a Green Line extension. This is because of the shorter added running time on the Green Line, and use of two-car trains instead of the six-car trains that will be used on the Blue Line by 2020. The Blue Line extension also includes a related cost of $37.5 million for a new equipment maintenance facility near Lechmere, because the present Blue Line shops could not accommodate an additional 50 cars. Existing Green Line shops and a new Lechmere facility planned independently of a Medford extension could service the 10 additional Green Line cars. Finally, construction costs for rapid transit stations are higher than for surface Green Line stations.

As stated above, the highest ridership would be achieved through the combination of the Green Line extension to Medford Hillside and the Red-Blue Connector. This combination of projects would also result in much lower costs ($225.5 million versus $548.4 million).

Capital costs per new weekday transit rider would be $27,700 for a Blue Line extension to Charles, and $75,300 for a Blue Line extension all the way to Medford Hillside. Examined separately, the capital cost per new transit rider for the Charles-Medford Hillside segment of the Blue Line to Medford Hillside extension would be $202,000. In this measure, it would be one of the least cost-effective of the PMT projects.

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[41] Costs do not include land acquisition.

A Green Line Medford Hillside extension alone would cost $24,000 per new weekday transit rider. The combination of a Blue Line extension to Charles and a Green Line extension to Medford Hillside would result in an average cost per new transit user of $26,100. Either separately or in combination, these would be among the more cost-effective of the PMT projects in this measure.

For the Blue-Red connector, the annual cost per hour of travel time savings, would be among the lowest for all rail extensions examined, at $4.73. The Green Line Medford Hillside extension would be more costly in this measure, at $11.02, but would nevertheless be among the lower cost rail projects. A Blue Line Medford Hillside extension would cost $31.38 per hour of time savings overall. The Charles-Medford Hillside segment alone would cost $644 per hour of travel time savings, making it by far the most costly PMT project in this measure.

Air Quality Impacts

For its length, the Red - Blue Connector would provide large air quality benefits, reducing regional emissions by 0.05 percent. The capital cost per kilogram of VOC eliminated per weekday would be in the mid-range for PMT projects, at $3.2 million (see Table G-75).

Table G-75
Air Quality Impacts of Blue/Green Line Extensions

	% Reduction Regional Emissions	Capital Cost/kg of VOC Elim/weekday
Green Line to Medford Hillside	0.06%	$1,860,500
Red - Blue Connector	0.05%	$3,241,400
Blue Line to Medford Hillside	0.08%	$8,284,300

A further extension of the Blue Line beyond Charles to Medford Hillside would reduce emissions an additional 0.03 percent to a total of 0.08 percent. However, the cost per kg of VOC eliminated would increase significantly to $8.3 million For the Charles-Medford Hillside segment alone, the capital cost per kilogram of VOC eliminated would among the highest for any PMT project, at $17.2 million. For a Green Line Medford Hillside extension alone, the capital cost per kilogram of VOC eliminated would be $1.9 million. This would be among the lowest such costs for all rail extension projects examined.

The combination of the Red-- Blue Connector with a Green Line extension to Medford Hillside would be much more cost effective in achieving air quality improvements than a Blue Line extension to Medford Hillside. For the combination, regional emissions would be reduced by 0.08 percent, and the capital cost per kilogram of VOC eliminated would be $2.5 million.

Conclusions

A Green Line extension would provide better service to downtown Boston from the Lechmere-Medford Hillside corridor than a Blue Line extension, because of the greater number of downtown destinations served directly by the Green Line. In spite of slightly less frequent service assumed for a Green Line extension, combined with a Red - Blue Connector it would attract more new transit riders than a Blue Line extension to Medford Hillside (8,630 versus 7,280 per weekday).

Also, whether considered individually or in combination, the Red - Blue Connector and the Green Line extension from Lechmere to Medford Hillside are among the better projects examined for the PMT in terms of capital cost per new weekday transit rider, annual cost per hour of travel time saved, and capital cost per weekday kilogram of VOC eliminated. In combination, they are among the better PMT projects in reductions of regional emissions (a total of a 0.08 percent reduction). Either project could be built independently of the other. Of the two, the Green Line extension would require a lower total investment and would be more cost-effective in terms of environmental benefits. The Red - Blue Connector would, however, attract more new transit riders, and would have greater travel time benefits. This connector would also fill a gap in the existing rapid transit system, as opposed to extending the system outward.

A Blue Line extension to Medford Hillside would be contingent on construction of the Red - Blue Connector. Evaluated as a separate project, the Charles-Medford Hillside section compares unfavorably with other PMT projects in every measure, especially cost. The Lechmere-Medford Hillside corridor could be served much more cost-effectively by a Green Line extension than by a Blue Line extension.

Blue Line Extension to Riverside

Existing Conditions

The Blue Line currently runs from Wonderland Station in Revere to Bowdoin Station in the Government Center area of downtown Boston. At six miles, it is the shortest of the MBTA's three high-platform rapid transit lines. It is also the only one of the three terminating in the Boston Central Business District instead of running through between termini on opposite sides. The Blue Line has direct connections with the Orange and Green Lines, but not with the Red Line.

The Green Line Central Subway consists of a light rail tunnel in Boston from west of Kenmore Square to north of Haymarket Square, with a branch from west of Symphony Station to Copley Square, and an elevated line from near Haymarket to Lechmere Square in East Cambridge. All service in the Central Subway is currently provided by trains originating at points on the surface B, C, or D lines west of Kenmore, or the surface E Line west of Symphony. In the Central Subway, B and D Line trains are scheduled to terminate at Government Center Station, C Line trains at North Station, and E Line trains at Lechmere. (Terminal assignments are revised from time to time as demand and operating requirements dictate.) Only trains going to Lechmere run through between opposite sides of the Boston CBD, and Lechmere is less than half a mile from the CBD border.

The surface portion of the D Line runs from the Fenway portal west of Kenmore Station through Brookline and Newton to Riverside Station at Route 128 (I-95). There are 13 surface stations. Unlike the other three Green Line branches, the D Line is entirely on a private right of way (a former commuter rail line). No public roads cross the D Line at grade.

The surface portion of the E Line runs from the Huntington portal west of Symphony Station via a center-of-street reservation on Huntington Avenue to Brigham Circle (Francis Street.) It then continues on unprotected in-street trackage on Huntington Avenue and South Huntington Avenue to Heath Street Loop. There are four stops within the reservation, and four on the street. The Heath Street Loop is on an easement on the grounds of the Jamaica Plain VA Hospital.

From Heath Street, the E Line formerly continued on in-street trackage via South Huntington Avenue, Centre, and South Streets to Arborway Terminal (Forest Hills). Service between Heath Street and Arborway was suspended in December 1985, originally because of road construction, but was never resumed. Restoration of service on this segment is addressed as a separate PMT project.

At present, passengers can transfer between the Blue and Green Lines at Government Center Station. The tracks of the two lines are on different levels of the station, and do not connect anywhere. Blue Line cars are equipped only for high-platform loading. Green Line cars are equipped only for low-platform loading.

PMT Alternatives

The PMT analysis examined three alternatives for extending the Blue Line from Downtown Boston to Riverside Station in Newton, replacing part or all of the existing Green Line D (Riverside) Branch. These alternatives are identified as

1. Via Esplanade (Rivervision)

2. Via Huntington Avenue

3. Via Newbury Street

They are described below in greater detail.

Blue Line Extension to Riverside – via Esplanade (Rivervision)

This alternative would start with an extension of the Blue Line from Bowdoin Station in a tunnel under Cambridge Street to Charles Station on the Red Line. From there, the tunnel would then continue along the Charles River, generally on the alignment of Storrow Drive, to Kenmore Square. There would be stations at the Hatch Shell (near Arlington Street), at Massachusetts Avenue, and at Kenmore. West of Kenmore, the extension would join the right of way of the Green Line D Branch, which it would use to Riverside (see Figure G-43).

The only present Central Subway station for which Rivervision would provide a direct replacement would be Kenmore. The Hatch Shell Station would be about 1,600 feet from Arlington Station, and Massachusetts Avenue would be a similar distance from Hynes/ICA. Both would be in predominantly residential areas, with all development on the south side because of the Charles River on the north. The Massachusetts Avenue Station would have access from Cambridge via the Harvard Bridge, but the bridge alone is nearly one half mile long.

Blue Line Extension to Riverside via Huntington Avenue

Like Rivervision, this alternative would start with an extension of the Blue Line from Bowdoin Station to Charles Station. From there, it would continue in a deep-bore tunnel more or less in a straight line to a new station near Copley Square. There would be one intermediate station near Beacon and Arlington Streets.

West of Copley Square, the extension would use the present Green Line Huntington Avenue Subway to Symphony Station. (The Prudential and Symphony Stations would be converted to high-platform loading.) Beyond Symphony, the subway would be extended under Huntington Avenue and connecting roads to Brookline Village. This segment would include stations near the Museum of Fine Arts and at Longwood Avenue on Huntington Avenue. The Green Line D Branch alignment would be used from Brookline Village to Riverside (see Figure G-44).

This extension would eliminate the E Line entirely and replace the surface D Line west of Brookline Village. A truncated D Line would run from Brookline Village into the Central Subway.

Figure G-43
Blue Line to Riverside: Rivervision Alignment

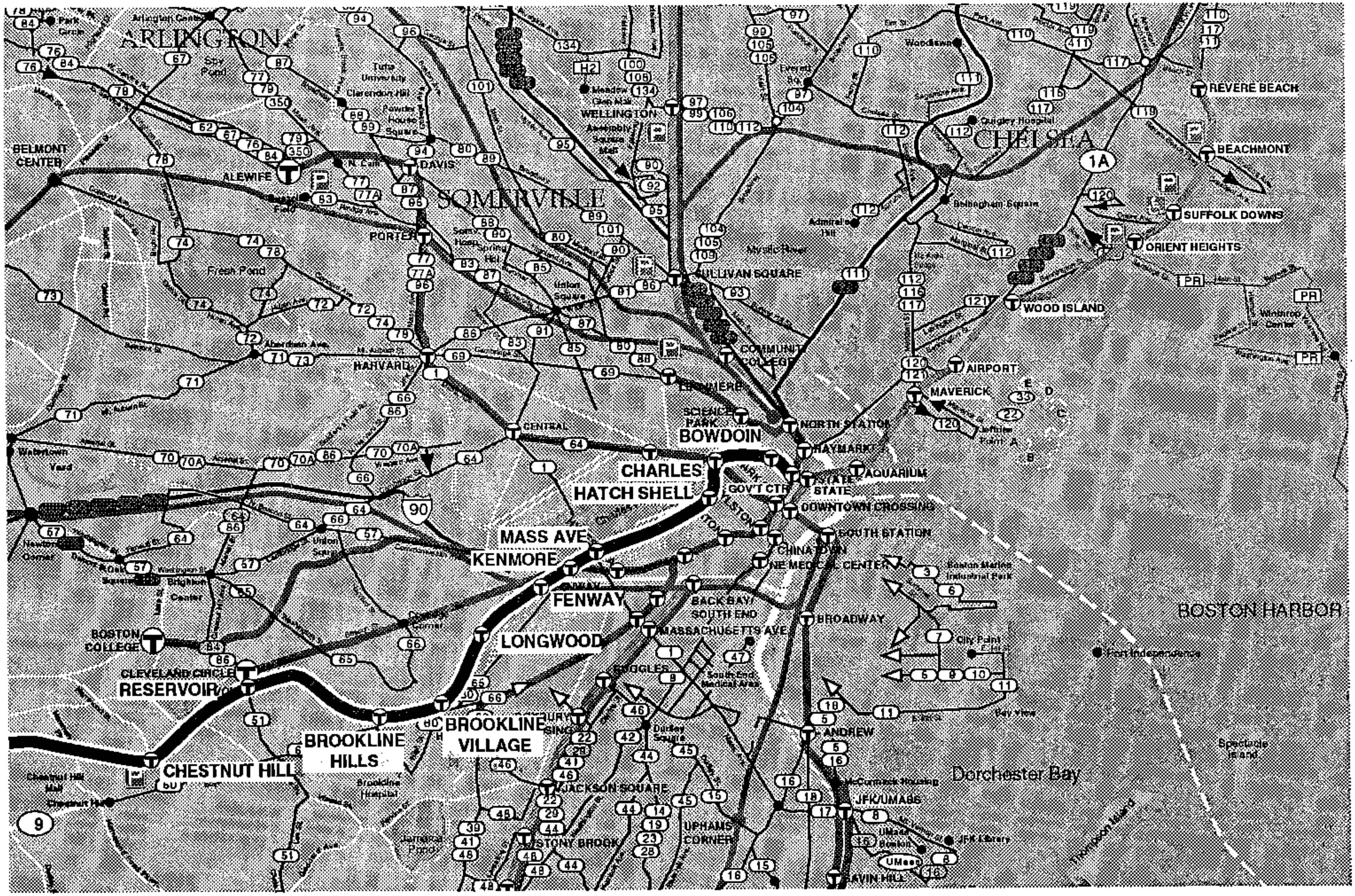
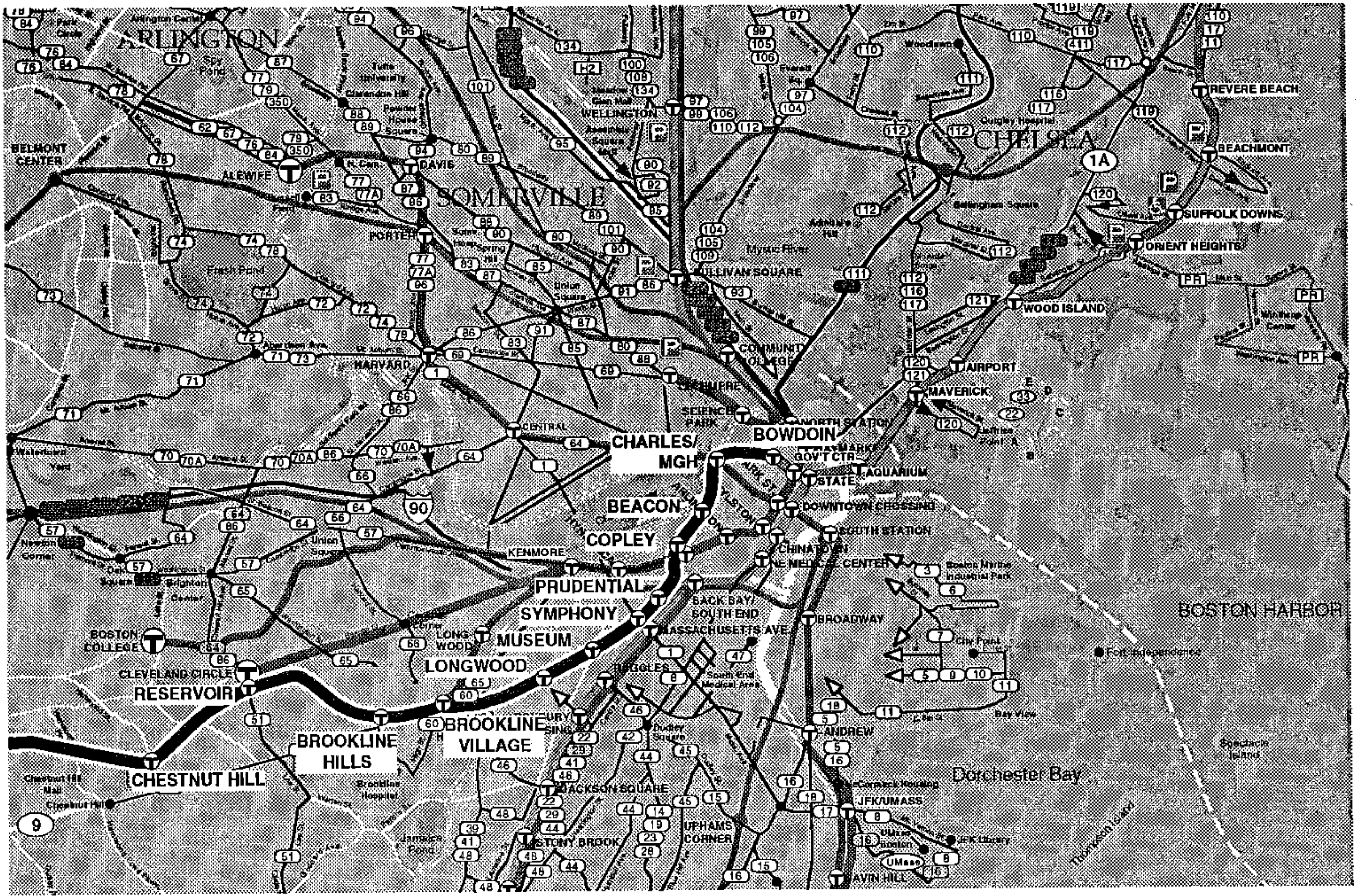


Figure G-44
Blue Line to Riverside via Huntington Avenue



Blue Line Extension to Riverside via Newbury Street

Under this alternative, the Government Center Blue Line platforms would be reoriented toward the southwest, from which point the Blue Line would continue parallel to the existing Green Line to Park Street. It would have platforms there below the Red Line. It would then take a direct route via deep bore tunnel under Boston Common and the Public Garden from Park Street to Newbury Street at Arlington Street. From there, it would run under Newbury Street to Massachusetts Avenue, and parallel with the Massachusetts Turnpike to Kenmore Square. Beyond Kenmore, it would join the D Line and continue to Riverside (see Figure G-45).

Besides Park Street, the new line would have stations at Arlington Street, Dartmouth Street, Massachusetts Avenue, and Kenmore Square. Each of these would have a pedestrian connection with the nearest parallel station in the Central Subway. The only Green Line Station between Government Center and Kenmore that would not gain a Blue Line alternative would be Boylston.

Ridership Impacts

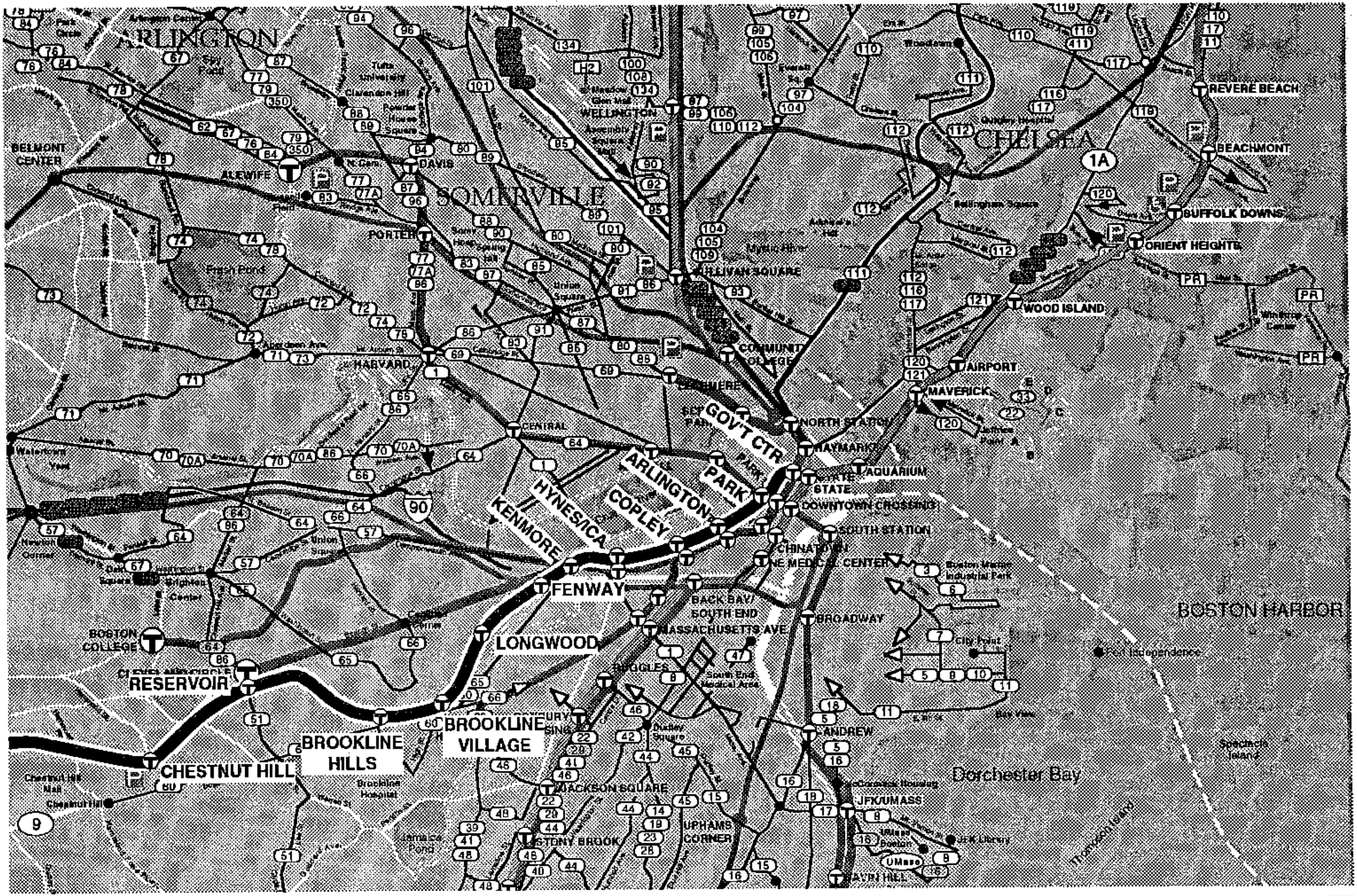
The PMT demand forecasts for the year 2020 indicate that the Rivervision alternative would serve 70,500 weekday riders, of which 8,000 would be new transit users (see Table G-76). The Huntington Avenue alignment would serve 81,400 riders, including 8,700 new transit users. The Newbury Street alignment would serve 84,610 riders, including 10,240 new transit users. These figures put the Blue Line extensions in the upper ranks of all PMT projects studied, following only the Inner Circumferential light rail line and the North-South Rail Link.

Table G-76
Ridership Impacts of Blue Line Extensions to Riverside

	Total Trips	New Transit Trips	Travel Time Savings (hr/yr)
Rivervision	70,500	8,000	1.0m
Huntington Avenue	81,400	8,700	1.5m
Newbury Street	84,610	10,240	1.9m
Red-Blue Connector	19,210	4,970	0.8m

Between 49 and 62 percent of the new transit ridership for all three alternatives would be the result of providing a direct transfer between the Blue and Red Lines. A Blue Line extension from Bowdoin Station only as far as Charles Station would attract 4,970 new transit trips. A Blue Line extension from Government Center only as far as Park Street was not modeled separately. Such an extension would probably attract slightly greater ridership than a Bowdoin-Charles connector, because of the more convenient location of Park Street as a final destination and as a transfer point with the south end of the Red Line. For the Rivervision and Huntington Avenue alignments respectively, 3,030 and 3,730 new trips would be attracted by the extensions beyond Charles Station. For the Newbury Street

Figure G-45
Blue Line to Riverside: Newbury Street Alignment



alignment, up to 5,270 new trips would be attracted by the extension beyond Park Street. These are also among the higher new ridership totals for individual PMT projects.

Each alternative would include a combination of direct replacements of existing Green Line segments with Blue Line segments and Blue Line extensions to areas not currently served by the Green Line. Some present Green Line users would be able to continue to travel without transfer between stations at or near their present boarding and alighting stops. Some would gain direct service to stations nearer to their ultimate origins or destinations than the present ones. Others would be forced either to transfer or to use less conveniently located stations. Access to Logan Airport and the North Shore from Newton, Brookline and the Back Bay would be improved under all three options.

Congestion in the Green Line Central Subway would be reduced under all three alternatives, but to the greatest extent under the Newbury Street scheme. The removal of part or all of the D Line and possibly also the E Line from the Green Line subway would allow more frequent service to be run on the B and C Lines (and on the E Line, except with the Huntington Avenue alternative).

Of the three alternatives, the Huntington Avenue alignment would provide the greatest change in service compared with current operations. Connections between Newton, Brookline, the Longwood Medical Area and Mass General Hospital would be significantly improved. In addition, the institutional area along Huntington Avenue would receive a higher level of service than is currently provided by the E Line. The conversion to rapid transit would, however, reduce the number of stops along Huntington Avenue. This would increase walking access distances for many passengers compared to E Line service.

Travel time savings would be very high for all three alternatives. The Rivervision alignment saves 3,292 hours per weekday or 1.0 million hours per year for base-case riders. The Huntington Avenue route would save 4,847 hours per weekday or 1.5 million hours per year. Finally, the Newbury Street alignment would save 6,244 hours per weekday or 1.9 million hours per year. These are very high figures: the only other PMT project with savings of over one million hours per year would be a circumferential light rail line. (Travel time savings for the North–South Rail Link have not yet been calculated).

Costs and Cost-Effectiveness

Any of the alternatives for extending the Blue Line to Riverside would be among the most costly of all PMT projects examined. Of the three, the Huntington Avenue alignment would have the lowest capital cost, at $883.5 million. Rivervision would be next, at $985.5 million (see Table G-77). The Newbury Street alignment would be the most expensive, at $986 million. The differences in cost have to do primarily with the amount of tunneling involved. The Huntington Avenue alignment would be the least costly because it would use the existing Huntington Avenue Subway. All subway sections on the other two routes would be new.

Although all three alternatives would stimulate large increases in transit ridership, their very high capital costs would result in costs per new transit user ranging from $96,290 for the Newbury Street alignment to $123,188 for Rivervision. This would make them among the most expensive PMT projects in this measure.

Annual operating costs for the three Blue Line Riverside alternatives would be among the highest for all PMT projects, ranging from $10.4 million for the Huntington Avenue route to

$12.1 million for the Newbury Street route. These costs would be exceeded only by those of the Circumferential Transit Full LRT option, the New Bedford/Fall River commuter rail extension, and the North-South Rail Link. Operating costs for Blue Line extensions to Lynn or Medford Hillside would be similar to those of the Riverside extensions.

The operating cost calculations for Blue Line Riverside extensions take into account reductions in Green Line operations that would result from replacement of the D or E Lines with rapid transit. Blue Line cars are less expensive to operate than Green Line cars, but a Blue Line extension would use four or six-car trains compared to present operation of single cars and two-car trains on the D and E Lines. Therefore, Blue Line service would involve large increases in vehicle hours and vehicle miles.

Table G-77
Costs of Blue Line Extensions to Riverside

	Operating Cost (Annual)	Fare Revenue (Annual)	Capital Cost[42]	Capital Cost/ New Trip	Cost/ Pass. Hr. Saved
Riverview	$11.0m	$1.7m	$985.5m	$123,190	$41.73
Huntington Avenue	$10.4m	$1.9m	$883.5m	$101,550	$28.44
Newbury Street	$12.1m	$2.2m	$986.0m	$96,290	$22.77

The Huntington Avenue extension would remove the junction of the E Line with other Central Subway routes just west of Copley Station. This would result in a slight reduction in travel time for Green Line cars and could produce some additional operating cost savings not included in the calculations above.

Fare revenue for the Blue Line Riverside extensions would be relatively high, because of the large number of new transit users. The revenue totals, ranging from $1.7 million for the Rivervision route to $2.2 million for the Newbury Street option would be among the highest of all the rapid transit projects. Inner Circumferential light rail transit, the Worcester and New Bedford/Fall River commuter rail extensions and the North-South Rail Link would all generate higher fare revenue.

The costs per passenger hour saved for the Blue Line Riverside extensions would be among the lower of such costs for rapid transit extensions examined in the PMT, because of the very high levels of travel time savings. The dollar figures range from $22.77 per hour for the Newbury Street route to $41.73 for the Rivervision route.

Air Quality Impacts

The Blue Line Riverside extensions would be among the better PMT projects in terms of air quality improvements (see Table G-78). Reductions in regional emissions would be 0.08 percent for Rivervision, 0.09 percent for Huntington Avenue, and 0.12 percent for Newbury

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[42] Costs do not include land acquisition.

Street. The Riververvision and Huntington Avenue alignments would include the Bowdoin-Charles Blue Line-Red Line connector. That segment alone would reduce regional emissions by 0.05 percent. The Newbury Street alignment would include an alternate Blue-Red connector from Government Center to Park Street, with probable similar air quality benefits.

The air quality improvements resulting from the Blue Line extensions would be among the most expensive to attain of all PMT projects. The capital cost per weekday kilogram of VOC eliminated would range from $9,720,000 for the Newbury Street alignment to $14,156,800 for Riververvision. Excluding improvements that could be attained just by extending the Blue Line to the Red Line, the capital cost per weekday kilogram of VOC eliminated would be $14,381,360 for Newbury Street, $25,547,950 for Huntington Avenue, and $31,176,500 for Riververvision.

Table G-78
Air Quality Impacts of Blue Line Extensions to Riverside

	% Reduction Regional Emissions	Capital Cost/kg of VOC Elim/weekday
Riververvision	0.08%	$14,156,800
Huntington Avenue	0.09%	$12,345,400
Newbury Street	0.12%	$9,719,700

Conclusions

A Blue Line extension to Riverside via any of the three alignments examined would produce large gains in ridership, very large travel time savings, and relatively large air quality improvements. However, these benefits would be very costly to attain: two of the three alignments would cost nearly $1 billion, and the third nearly $900 million.

From a systems point of view, the extension of the Blue Line and conversion of the Riverside Line to rapid transit make sense. Rapid transit lines function most efficiently when through-routed, that is, running to the downtown area, through it and out the other side. The Riverside Line is a good candidate for rapid transit because it is grade-separated for its entire length.

On the other hand, the present Green Line service has not been shown to be grossly inadequate for the moderate density areas of Brookline and Newton. It would be difficult to justify spending so much money merely to upgrade an existing service rather than to bring a wholly new service to another area.

The benefits of connecting the Blue Line to the Red Line, and of providing direct airport service to Newton and Brookline should not be overlooked. In addition, all three options would reduce crowding on the Green Line and provide a capacity boost to transit in the densely developed Back Bay. The Huntington Avenue scheme would also be of benefit to the Longwood Medical Area, the institutional area and Massachusetts General Hospital.

In the long term, if Green Line congestion gets much worse, it may be necessary to add physical capacity through the Back Bay. At that point, the Blue Line extension may be a good choice.

In the short term, it appears that the Blue-Red connection is a beneficial and cost-effective project. The study of it should include the alternative routing to Park Street, so as not to preclude the future implementation of the Newbury Street scheme. For the Riverside Line, several improvements to Green Line service are possible at a much lower cost than a Blue Line extension.

The scope of the PMT extends only to 2010 or 2020. It does not appear that a Blue Line extension to Riverside is cost-effective enough to be considered within that time frame. The concept should be retained for further study for possible implementation after 2020.

Orange Line Extension to Needham

Existing Service

The Needham commuter rail line runs from South Station to Needham Heights. At 13.6 miles, this is the second-shortest MBTA commuter rail line. Needham trains, along with most Franklin Line and Attleboro/Stoughton Line trains, use Amtrak's Boston-New Haven Main Line between South Station and Forest Hills (5.2 miles), where the Needham Branch diverges. (Only Needham trains serve the Forest Hills commuter rail platform.) The Orange Line shares the right of way of the Main Line between Back Bay Station and Forest Hills.

At present, there are 17 trains in each direction on the Needham Line on weekdays. Eleven round trips cover the full route to Needham Heights. The other six run only from South Station to Needham Junction (12.0 miles). In AM peak hours, three of six inbound trains start at Needham Heights, at intervals of 42 and 48 minutes. Combined headways at Needham Junction range from 19 to 48 minutes. All five outbound PM peak trains run through to Needham Heights, at intervals of 30 to 40 minutes. Mid-day headways range from one to two hours, with no service to Needham Heights or Needham Center between 9:30 a.m. and 4:30 p.m. Evening headways range from 60 to 75 minutes, with all service running through to Needham Heights.

All peak- period peak-direction trains stop at all stations between South Station and Needham Junction or Needham Heights. Some off-peak and off-peak-direction trips skip one or more stations, mostly because of schedule constraints imposed by track layout.

PMT Alternative

The PMT analysis examined a possible replacement of Needham Line commuter rail service with an Orange Line extension. This extension would run from Forest Hills to Route 128 in Needham over the Needham Branch right of way (see Figure G-46). It would include stations on the sites of the present Roslindale, Bellevue, and West Roxbury commuter rail stations. New stations would be added at the VFW Parkway in West Roxbury and at Route 128 in Needham. The Highland stop in West Roxbury (0.46 miles west of Bellevue and 0.46 miles east of West Roxbury Station) would be discontinued.[43]

(The 1977 Revised PMT analyzed a similar project, but selection of a preferred choice between extending the Orange Line or upgrading commuter rail service was deferred pending further studies. The Needham Branch was shut down entirely from October 1979 to October 1987 because of construction work on the MBTA's Southwest Corridor Project north of Forest Hills. A final decision to reinstate commuter rail service to Needham was made in 1983. The reasoning behind this decision was not well documented at the time, but was partly a result of funding constraints.)

All Orange Line trains would run through to Route 128 instead of originating or terminating at Forest Hills. This would provide much more frequent service on this segment than is now provided by the Needham commuter rail line. Orange Line trains currently run on headways of 4.5 minutes during AM and PM peaks, eight minutes mid-day and early evening, and 13 minutes late evening. Peak headways would be shortened to 4.0 minutes by 2020.

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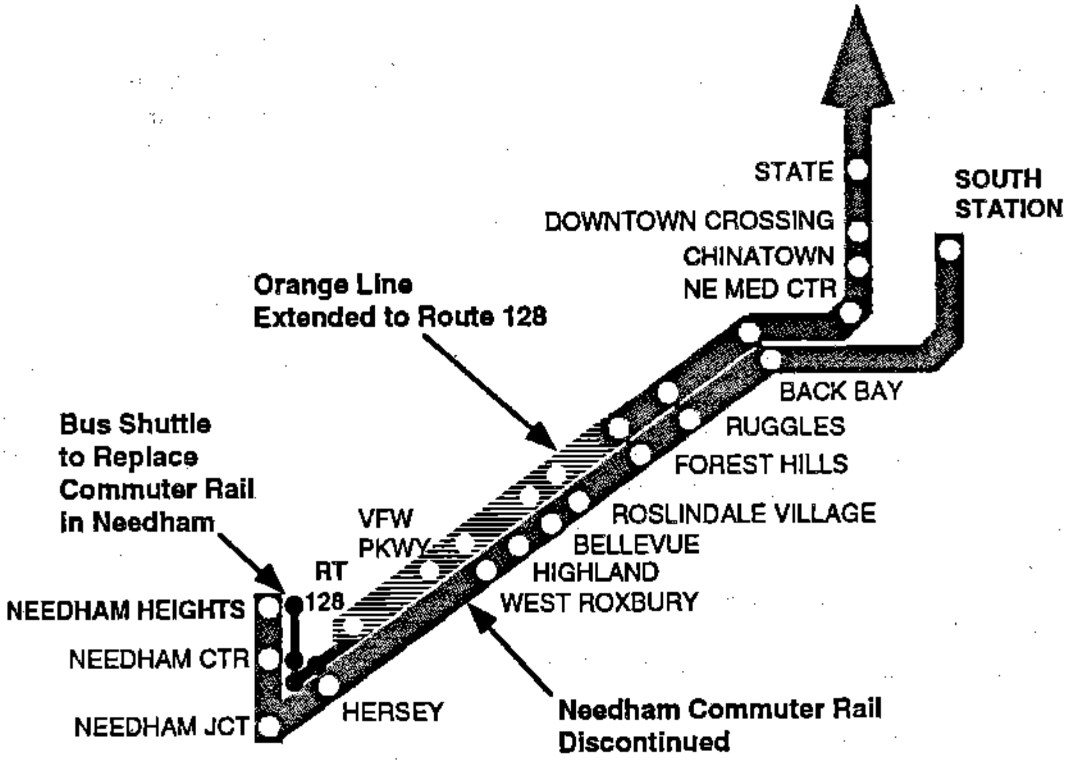
[43] Closing Highland would result in a loss of 178 existing parking spaces there. West Roxbury has 61 spaces, and Bellevue has 37.

The four existing commuter rail stations in Needham (Hersey, Needham Junction, Needham Center, and Needham Heights) are all beyond the proposed Route 128 Orange Line terminal. Rail service to these stations would be discontinued and replaced with feeder bus service via parallel streets to the new Route 128 Orange Line terminal.

Orange Line cars have faster acceleration than the diesel locomotive-hauled trains now used on the Needham Branch, allowing faster running times. The projected Orange Line time from West Roxbury to Forest Hills is 5.6 minutes, compared to the present commuter rail time of 12 minutes, or a saving of 6.4 minutes. This advantage would be partly offset by the faster commuter rail running time between Forest Hills and Back Bay (nine minutes versus 12 for the Orange Line). From points in Needham, travel times via the bus-rapid transit combination would exceed those of the present commuter rail service.

Figure G-46
Existing Needham Commuter Rail Line and Potential Orange Line Extension to Route 128



Ridership Impacts

An extension to Route 128 in Needham would increase Orange Line ridership by 13,650 trips per day in the year 2020. Of these, 4,700 would be new transit trips, and 8,950 would be diversions from transit services other than the Orange Line. The largest share of transit diversions to the extension (up to 5,100 per weekday) would come from the Needham commuter rail line, which would be discontinued if the extension were built. Some of the remainder would come from MBTA local bus routes. MBTA Routes 35, 36, and 37 parallel the Needham Branch between West Roxbury and Forest Hills. Of the riders on these routes, 45 percent already transfer to the Orange Line, but 55 percent make bus-only trips. An Orange Line extension would attract about 700 riders per weekday that would otherwise have made bus-only trips on Routes 35, 36, and 37. MBTA bus Routes 34, 40, 50 and 51 also parallel the Needham Branch between Roslindale and Forest Hills. About 175 additional bus-only trips would be diverted from these routes to the Orange Line extension.

Another likely source of transit rider diversions to an extended Orange Line would be the Green Line D Branch to the north. At present, the lower fares and greater service frequency on this line attract some riders from origins that are closer to Needham Branch stations. For many of these riders, an Orange Line extension to Route 128 would be preferable to the D Line. The Orange Line extension could also draw some riders away from the Franklin Branch commuter rail line to the south.

With an extension to Route 128 in Needham, there would be an estimated 8,600 weekday boardings at the five new stations in 2020. Forest Hills boardings would drop by about 1,075, making a net gain of 7,525 at Forest Hills and south. This total would include approximately 515 local round trips made entirely on the extension. There would be a net gain of 6,320 inbound trips on the present Orange Line north of Forest Hills. A similar number of outbound return trips from existing stations would be added.

The projection of 4,700 new weekday transit trips for the Route 128 Orange Line extension exceeds that of many of the other rail extensions examined for the PMT. The various proposed Blue Line extensions to Riverside would draw in part on the same market as an Orange Line Route 128 extension. The 10,240 new transit riders predicted for a Blue Line extension to Riverside via Newbury Street, is 2.2 times as great as predicted ridership for the Orange Line extension, but capital cost would be over 3.9 times as great, and operating cost 6.5 times as great for the Blue Line.

Costs and Cost-Effectiveness

The most recent capital cost estimate for an Orange Line extension to Route 128 is $249 million. The average capital cost per new weekday Orange Line rider would be $18,247. The average capital cost per new weekday transit rider would be $52,941. Both costs are lower than the average for all PMT projects examined. Several rapid transit extensions would have lower costs per total rider, but most would have higher costs per new rider.

Table G-79
Costs of Orange Line South Route 128 Extension

Operating Cost (Annual)	Fare Revenue (Annual)	Capital Cost	Capital Cost/New Transit Trip
$1.8m	$0.96m	$249.0m	$52,941

The Orange Line extension would generate estimated travel time savings of 1,525 hours per weekday, or 466,650 hours per year. These are higher than the savings for most other PMT projects examined. (The circumferential transit line and Blue Line extensions that include a Red Line connection would have larger savings.) The annual net cost per hour of travel time savings for the Orange Line extension ($22.22) would be significantly less than those of most of the other rapid transit extension projects examined.

The Orange Line extension would result in an increase of $1,872,000 in annual operating costs, compared to an increase of $957,000 in annual fare revenue. (These costs assume 4.0-minute peak-period headways and six-car trains.)

The Needham Branch now has a single track most of the way from Forest Hills to Needham Heights. There are passing sidings near Forest Hills, West Roxbury and Needham Junction. An Orange Line extension would require double track. The right of way would not have to be widened, because there was once double track all the way from Forest Hills to Needham Junction The one existing track has continuous welded rail, in service only since 1987. No major rehabilitation of this track would be needed for rapid transit conversion. Orange Line power distribution and signal systems would need to be installed throughout the route. The present low-platform commuter rail stations at Roslindale, Bellevue, and West Roxbury would need to be replaced with high-platform rapid transit stations.

All public road crossings of the Needham Branch between Forest Hills and Route 128 are already grade separated. At Forest Hills, the present Orange Line track layout was designed to allow for a future extension along the Needham Branch. No substantial construction would be required to form a connection there, but some reconfiguration of Orange Line storage tracks would be needed.

Recent plans to construct a commuter rail station and parking lot at the VFW Parkway on the site of an abandoned drive-in theater were dropped because of neighborhood opposition. The property is now being developed as a building supply center. There will not be room for significant surface parking for a future transit station. The 500 parking spaces assumed in PMT demand projections would require a garage.

The Route 128 Station site is surrounded by wetlands forming part of the Charles River flood plain. The 1,000 parking spaces assumed in the demand analysis would require construction of a garage on air rights over Route 128. Because of existing land use and street layouts, automobile access to such a station would have to be exclusively from Route 128. The exit ramp from Route 128 northbound to the garage would have to begin about one quarter of a mile from the bottom of the Great Plain Avenue on-ramp. This could cause problems if there was a backup of traffic entering the garage.

Pedestrian and bicycle access to the Route 128 Station from the west could be provided along the railroad right of way. The rail line is in a deep rock cut in this area. The nearest access point to a walkway would be at Great Plain Avenue, 0.8 miles from Route 128.

Operational Impacts

Operationally, a Route 128 extension would have limited impact on the Orange Line. When the 1989 CTPS passenger counts were conducted, the Orange Line had six-car trains on 4.5-minute headways during peak hours. In the peak 15 minutes, trains at the maximum load point on the south end of the line were loaded to an average of 66 percent of practical capacity. Therefore, ridership could grow 52 percent from this base before reaching capacity. Except in the peak 15 minutes, the margin for growth would be significantly greater. The estimated total boardings for the south end of the Orange Line in 2020 are 30 percent higher than the 1989 base with no extension and 60 percent greater with an extension. If the time distribution of riders and the proportion of riders on board at the peak load point in 2020 are similar to patterns in 1989, 4.5-minute headways would be adequate for an unextended Orange Line. The reduction to 4.0 minute headways assumed in the cost calculations would be adequate for the extended line.

Other than a possible slight increase in peak-period service, the number of trains passing over the existing line would be unchanged. Increased loads would result in slightly longer dwell times, causing increased running times. (With loads from a Route 128 extension, the running time between Forest Hills and Downtown Crossing would increase by less than a minute compared to the unextended line in 2020.)

The removal of Needham Branch commuter rail trains from shared tracks and platforms on the Main Line north of Forest Hills would free more capacity for Franklin and Attleboro/Stoughton commuter trains and for Northeast Corridor intercity trains along the Southwest corridor and at South Station. This will be a more important consideration if a North Station - South Station Rail Link is not built than if it is.

On the negative side, a Route 128 Orange Line extension would preclude a future commuter rail extension to points beyond Needham, such as Millis. Demand potential for such an extension now is moderate, and unexpected growth in demand in other corridors has shown that options should be kept flexible. (The Old Colony Lines restoration currently getting underway will require costly compensation for portions of right of way lost to the Red Line South Shore extension. Design decisions for the latter were made in the 1960s, under the assumption that commuter rail would never return to that corridor. Similarly, the design of the Oak Grove Orange Line extension now inhibits the operating efficiency of the Haverhill/Reading commuter rail line.)

Air Quality Impacts

An Orange Line extension to Route 128 in Needham is projected to reduce regional emissions by 0.05 percent. This is greater than the reductions for about two thirds of all projects examined for the PMT. The capital cost per kilogram of VOC eliminated per weekday would be relatively high, at $6,200,525. (Projects more costly in this measure would include Blue Line extensions to Riverside or Medford Hillside, a Red Line extension to Lexington, a circumferential light rail line, and the Rail Link.)

Conclusions

An Orange Line extension to Route 128 in Needham would attract a high number of new weekday transit riders (4,700). It would also be among the more expensive PMT projects, with a capital cost of $249 million. Passengers from both Needham and West Roxbury would gain much more frequent service than is now provided by the Needham commuter rail line. Many West Roxbury residents who now ride local buses to Forest Hills to transfer to the Orange Line would be provided with one-vehicle rides. Conversely, most users of the four present commuter rail stations in Needham would have to shift to the Route 128 Orange Line terminal, using feeder buses or private autos for access.

Daily two-way boardings for the 5.6-mile extension from Forest Hills to Route 128 are projected at 8,600 by the year 2020. This is an average of 1,536 boardings per mile, which is significantly lower than the present averages for any of the MBTA rapid transit extensions completed during the past 20 years. In 1989 CTPS counts, the Red Line South Shore extension, which includes a long non-stop segment, averaged 2,550 boardings per mile. The

Orange Line north of North Station averaged 5,338 boardings per mile, and the Red Line Alewife extension averaged 8,327.

Many of the capital improvements required for an Orange Line extension to Route 128 could be implemented in the form of gradual upgrading of the commuter rail line, rather than as a one-time conversion project. For example, a second track between Forest Hills and Route 128 would allow more frequent and reliable commuter rail service. High-level platforms suitable for Orange Line trains could also be used by commuter rail trains. (On the north end of the Orange Line, the Malden commuter rail stop uses a high-level platform originally intended to serve a third Orange Line track. A similar high-level platform at Oak Grove is used by commuter trains in emergencies, and has had scheduled service in the past.) New stations at the VFW Parkway or Route 128 could be used by either commuter rail or Orange Line trains. Garages could initially be constructed with the more limited capacity required by commuter rail demand, but designed to allow future expansion.

There is always uncertainty as to likely land use and travel patterns 20 or 30 years in the future. Therefore, adoption of a flexible strategy allowing future transportation facilities to match future needs is preferable to locking in choices now that may not be optimal for the future.

Green Line Restoration to Oak Square

Existing Conditions

The Green Line consists of four light rail routes operating on separate alignments west of the Boston Central Business District and sharing a subway and elevated structure within the CBD. The present routes and endpoints are as follows:

B Line: Boston College via Commonwealth Avenue and Subway to Government Center Station.

C Line: Cleveland Circle via Beacon Street and Subway to North Station.

D Line: Riverside Station via Highland Branch and Subway to Government Center Station.

E Line: Heath Street via South Huntington and Huntington Avenues and Subway to Lechmere Station.

The C and D Lines, respectively, enter the subway at portals east of Saint Mary's Street and Fenway Park Station, and join at Beacon Junction, west of Kenmore Station. The B Line enters the subway east of Blandford Street and joins the C and D Lines east of Kenmore Station. (Kenmore Station has separate tracks for the B Line and for the C and D Lines.) The E Line enters the subway east of Northeastern University and joins the other three lines at Copley Junction, west of Copley Station.

Outside of the Central Subway, only the D Line (built on a former commuter rail route) has an exclusive right of way. The B and C Lines and the portion of the E Line between Northeastern University and Brigham Circle (Francis Street) are located on center-of-street reservations. The remainder of the E Line from Brigham Circle to Heath Street runs on unprotected in-street tracks.

A fifth Green Line Branch, the A Line, formerly diverged from the B Line at Packard's Corner (Commonwealth Avenue and Brighton Avenue) in Allston and ran via Brighton Avenue, Cambridge, Washington, Tremont, Park, Centre and Galen Streets through Allston, Brighton, and Newton Corner to Watertown. This line was entirely on unprotected in-street trackage.

In June 1969, A Line light rail service was discontinued and replaced with MBTA bus Route 57 from Watertown to Kenmore Square. This conversion was prompted by a severe shortage of serviceable rolling stock for the Green Line. It was also a continuation of a long-term trend of light rail to bus conversions in Boston and other cities. The conversion was initially announced as a three-month trial, after which light rail service might be restored if buses proved to be unsatisfactory. The trial was subsequently extended to one year to obtain results from all seasons. At the end of a year, the conversion was made permanent.

After the bus conversion of the A Line, the Watertown carhouse at the outer end of the route was still needed for heavy repairs of vehicles for the remainder of the Green Line system. To provide access to the carhouse, the A Line tracks and power system have remained in place. The tracks have, however, deteriorated to far below acceptable standards for revenue service, and the power system is incompatible with the needs of present-day Green Line vehicles.

Service restoration would require almost total reconstruction of the line. Also, the present Green Line fleet is not large enough to serve the A Line in addition to existing routes.

Present non-summer weekday service on Route 57 is operated on headways of six to eight minutes peak, nine minutes mid-day, and 15 minutes evening. (Like many MBTA services, Route 57 has reduced frequencies in the summer when schools are not in session.)

In addition to Route 57, three MBTA express bus routes serve the A Line corridor. Route 301 starts at Brighton Center and runs west along the A Line route to Newton Corner. From there, it runs to downtown Boston on the Mass. Pike, exiting at Kneeland Street and terminating at Federal and Franklin Streets in the Financial District. Service is operated weekdays only, from about 6:30 to 9:30 a.m. and 2:00 to 6:30 p.m. with headways of four to ten minutes.

Route 304 starts at the Watertown carhouse and follows the A Line route to Newton Corner, and the Mass. Pike to Boston. Like Route 301, it terminates at Federal and Franklin Streets. Route 302 is similar to Route 304, but runs to the Prudential Center and Copley Square instead of Franklin Street. Route 304 operates Monday through Saturday. Weekday peak headways range from seven to ten minutes from Watertown, alternating with short-turns from Newton Corner on equal headways. Mid-day and evening service runs every 30 minutes, but is combined with Route 302 to serve both Copley Square and Franklin Street. Route 302 runs weekdays only, with peak headways of 10 to 15 minutes.

Routes 301, 302, and 304 were all started before the discontinuance of A Line service. Surveys and passenger counts showed that the ridership on these routes was largely diverted from the A Line.

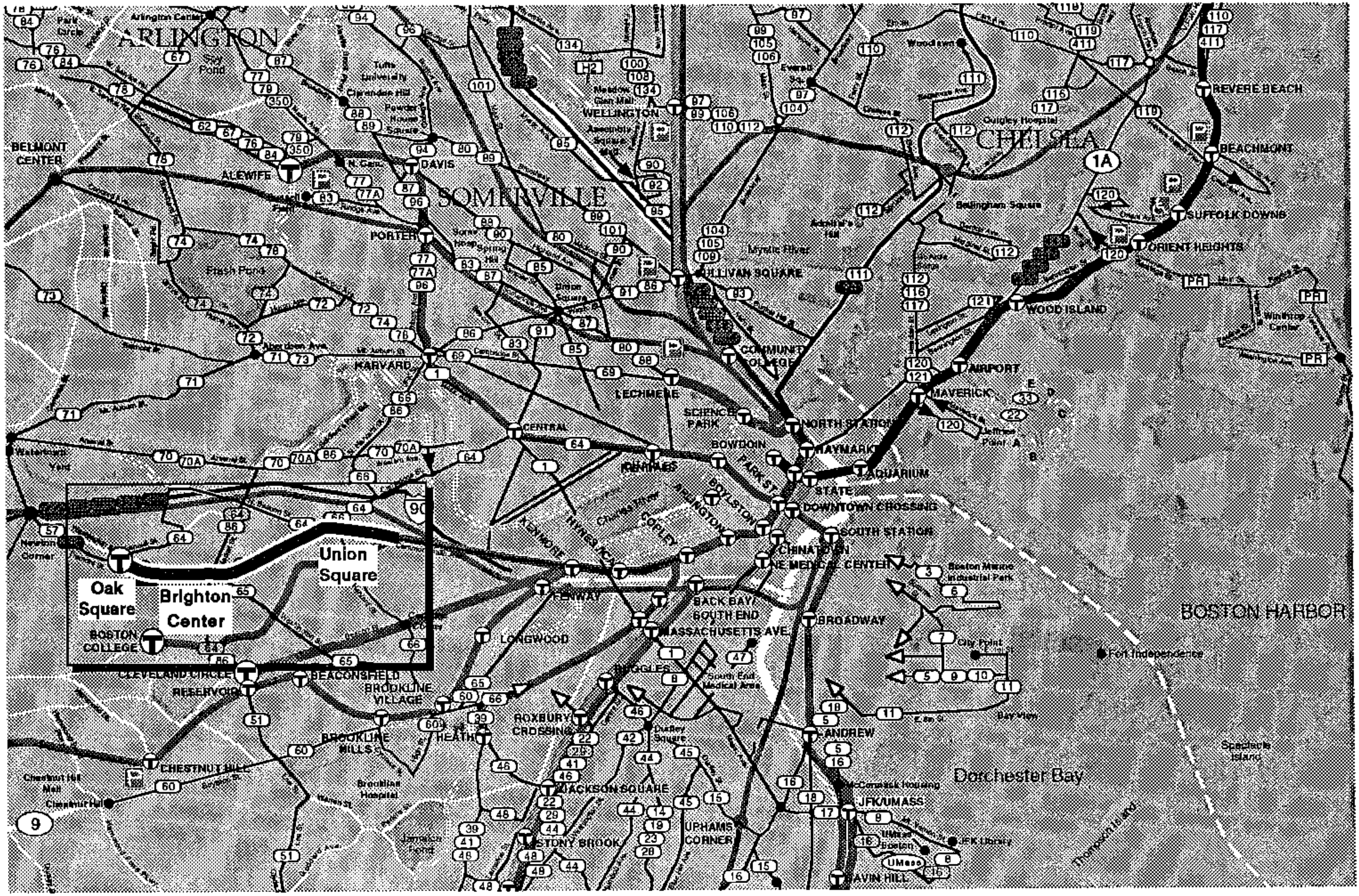
PMT Alternative

The PMT analysis examined a possible reinstitution of light rail service on the segment of the A Line between Packard's Corner and Oak Square (Washington and Tremont Streets) in Brighton. This would include 2.2 of the total 3.9 route miles between Packard's Corner and Watertown(see Figure G-47).

Oak Square was used as the terminal for purposes of analysis for several reasons. Previous studies have found that with maximum feasible upgrading, A Line travel times to downtown Boston would be less than or equal to express bus times from points east of Oak Square but not from points between Oak Square and Watertown. In the past, the only off-street turnback facility on the A Line between Packard's Corner and Watertown was a loop over private right of way at Oak Square. (This loop still exists, but like the rest of the A Line it would need major rehabilitation for revenue service.)

Because of narrow streets, and the location of the A Line tracks at the crossing of the Mass. Pike, resumption of light rail service would worsen already severe traffic congestion around Newton Corner and between there and Watertown. In past public hearings, representatives of the City of Newton and the Town of Watertown have testified against restoration of light rail service between Newton Corner and Watertown. Termination of the A Line at Newton Corner would be feasible in conjunction with a proposed bus and commuter rail station to be built on air rights over the Mass. Pike. This proposal, initiated by the City of Newton, has been dormant for several years because of a lack of funds.

Figure G-47
Green Line to Oak Square



Ridership Impacts

The PMT forecasts indicate that A Line service re-instituted as far as Oak Square would carry 32,940 weekday riders (16,470 in each direction) in 2020. (This includes not only passengers with at least one trip end between Oak Square and Packard's Corner but also passengers using A Line cars for travel entirely on Green Line segments currently in service east of Packard's Corner.) Only 1,010 of these would be new transit riders. The remainder would be diverted from other Green Line branches (mostly the B Line) and from MBTA local and express bus routes. The analysis assumed that Route 57 would be discontinued, with replacement service between Oak Square and Watertown being provided by an extension of Route 64 (Central Square, Cambridge–Oak Square.) Service on Route 301 would be reduced by one third, but Routes 302 and 304 would not be altered.

Table G-80
Ridership Impacts of Green Line Restoration to Oak Square

Total Ridership (Daily)	New Riders (Daily)	Travel Time Savings (Annual)
32,940	1,010	173,810 hrs.

Costs and Cost-Effectiveness

The estimated capital cost for restoration of A Line service to Oak Square is $93.8 million. Of this, $5.4 million would be for renovation of the track and power system between Packard's Corner and Oak Square. (This figure is based on an examination of upgrading needs done by the MBTA Engineering Department in 1986. Further deterioration since then could make costs much higher.[44]) The remaining $88.4 million represents the net cost of purchasing 34 new low-floor light rail vehicles. (The requirement of 34 vehicles is based on peak headways of five minutes with two-car trains assumed in the demand projections. A peak headway of seven minutes would provide sufficient capacity for the projected ridership. This would reduce the vehicle requirement to 24, and the vehicle cost to $62.4 million.) The capital cost estimate does not include improvements suggested in past studies, such as an extension of the center-of-street reservation west of Packard's Corner, or a subway at Brighton Center.

Including associated changes in bus service, operation of Green Line service to Oak Square on five-minute peak headways would increase annual operating costs by $8.6 million per year. Because most of the riders would be diverted from other MBTA services, only $425,000 per year in fare revenue from new riders would be generated. This would result in a revenue to cost ratio of only five percent. (Operating cost increases could be reduced by lengthening headways, but any reasonable service assumption would result in very low cost recovery.)

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[44] The state budget for fiscal 1994, approved after the PMT analysis was conducted, includes a provision requiring the MBTA to remove the A Line tracks entirely by June 30, 1994. Barring any subsequent changes in this requirement, a future restoration of the A Line would involve entirely new construction rather than rehabilitation. Capital costs for such construction have not been estimated.

Table G-81
Costs and Revenues of Green Line Restoration to Oak Square

Operating Cost (Annual)	Fare Revenue (Annual)	Capital Cost	Capital Cost/ New Trip
$8.6m	$425,000	$93.8m	$93,240

In the past, the inner terminal for A Line cars was Park Street Station. This is the first station in the subway with turnback facilities suitable for revenue service and accessible from the A Line. (The Kenmore Loop connects only with the tracks used by the C and D Lines.) The PMT capital and operating cost estimates assume that Park Street would again be the A Line terminal. Some proponents of A Line restoration have argued that only the costs for service from Oak Square to Kenmore should be allocated to the A Line, with the remainder being charged to general improvement in Central Subway service. This argument has merit to the extent that A Line service in the subway would either allow service reductions on existing routes, or avoid service increases that would otherwise be needed to meet demand. Determination of the full implications of A Line service on subway operations would require a far more detailed analysis than was possible in conjunction with the PMT. Based on findings of past studies, the costs of A Line operation within the subway would greatly exceed related savings on the other lines.

At the estimated demand level, the A Line to Oak Square would have a capital cost per new transit rider of $93,240. In this measure, it would be more expensive than the majority of rail extension projects examined for the PMT. The Oak Square A Line would not be significantly faster than the base-case alternatives. Hence, the annual cost per hour of travel time savings would also be relatively high, at $68.77.

Air Quality Impacts

Because most of the ridership on an A Line extension to Oak Square would be diverted from other transit services rather than from automobiles, environmental benefits would be relatively small. Regional emissions would be reduced by 0.01 percent. The capital cost per kilogram of weekday VOC eliminated would be $10,631,300. This is less than the unit costs for most of the rapid transit extensions examined, but greater than those for most of the commuter rail extension or improvement projects.

Accessibility and Traffic Flow

A further complicating factors involved with A Line service between Packard's Corner and Oak Square is the accessibility requirements contained in the Americans with Disabilities Act. Accessibility has serious implications for the Green Line, even beyond the necessity to operate the service with low-floor vehicles. Current designs for low-floor cars maintain a height of 10 to 14 inches above the top of the track (similar to the height of the first step in the present Green Line vehicles). In order to have level access, the Green Line vehicles would have to stop at platforms the same height as the low floor. For the branches in street reservations this is not a serious problem, but for the A Line beyond Packard's Corner, this would be much more difficult since the tracks run unprotected in the centers of streets.

At one time, the A Line reservation continued 0.7 miles further west to Union Square. A reservation could again be provided on that segment, but would add to the capital costs stated above. For the final 1.5 miles to Oak Square, street widths would preclude construction of a reservation without a severe loss of capacity for other traffic.

To provide accessibility for passengers in wheelchairs, the A Line tracks would have to be shifted from street centers to curbsides at least at stops. Weaving across lanes would have serious impacts on traffic flow. Relocating all of the trackage next to sidewalks would alleviate such traffic problems, but would eliminate all of the on-street parking along the route, including the busy commercial district of Brighton Center. A proposal to place the Brighton Center segment in a subway was examined in a previous study of the A Line, but would add at least $18.5 million to the project cost at 1993 prices.

Conclusions

A restoration of A Line light rail service between Packard's Corner and Oak Square should be given low priority. Such a project would have high capital and operating costs but small transportation or environmental benefits. Because of deterioration and obsolescence of the fixed facilities on the A Line, restoration of passenger service would require extensive reconstruction. Recent legislation requiring dismantling of existing A Line facilities would necessitate total reconstruction in the event of future service restoration. The largest component of the restoration expenses included in the PMT analysis would be acquisition of rolling stock. Under present law, the A Line would have to be operated with low-floor cars. These are currently more expensive than any other vehicles used by the MBTA. Even these cars would not completely solve accessibility problems on the route without further modifications at loading areas.

Most riders that would use the A Line would be diverted from other MBTA services, and would experience little reduction in travel time. Reductions in Central Subway crowding as a result of operating A Line service could be achieved more efficiently by adding service to the present subway routes.

Green Line Restoration to Arborway
Arborway Trackless Trolley

Existing Conditions

The Green Line consists of four light rail routes operating on separate alignments west of the Boston Central Business District and sharing a subway and elevated structure within the CBD. Outside of the Central Subway, only the D Line (built on a former commuter rail route) has an exclusive right of way. The B and C Lines and the portion of the E Line between Northeastern University and Brigham Circle (Francis Street) are located on center-of-street reservations. The remainder of the E Line from Brigham Circle to Heath Street runs on unprotected in-street tracks.

From Heath Street, the E Line formerly continued on in-street trackage via South Huntington Avenue, Centre, and South Streets to Arborway Terminal (Forest Hills). Because of subway modifications required for the Type 7 Green Line cars and a scheduled re-paving project on Huntington Avenue, E Line service was suspended in December 1985. Substitute service was provided by new MBTA bus Route 39 from Arborway to Copley Square. E Line service resumed as far as Brigham Circle in the Summer of 1986. Because of delays in the paving project, E Line service between Brigham Circle and Heath Street did not resume until late in 1989.

Permanent bus replacement of "outer" E Line service between Arborway and Heath Street or Brigham Circle had been under consideration by the MBTA for years prior to the 1985 shutdown. Among the reasons was that the Southwest Corridor Orange Line relocation was expected to cause a large decline in outer E Line ridership. An extensive alternatives analysis for the E Line corridor was undertaken in 1987. E Line service has not resumed between Heath Street and Arborway, but there has been no decision to make the bus conversion permanent.

A major complicating factor in restoration of E Line service has been changes in federal laws pertaining to accessibility for people with disabilities. At present, no part of the Green Line is accessible. This can continue for the time being, because the service is already in place, but will need to be corrected with future improvements and vehicle purchases. Because of the length of time the outer E Line has been shut down, it would now be subject to regulations for new services. Hence, re-opening could not precede the design and procurement of accessible Green Line vehicles.

At present, E Line light rail service operates from Heath Street to Lechmere Station. Non-summer weekday headways are eight minutes peak, nine minutes mid-day, and 10 minutes evening. Two-car trains are run except in the evening. Additional short-turn service is run as needed from Northeastern University or Brigham Circle to the subway. The Route 39 substitute bus service for the outer E Line now runs from Forest Hills Station to Back Bay Station via Copley Square. Weekday headways are three to four minutes in peak hours and five to seven minutes at other times.

PMT Alternatives

For the PMT analysis, two service alternatives for the currently inactive segment of the E Line between Heath Street and Forest Hills/Arborway were examined. These were:

1. Restoration of through Green Line service between Arborway and the Central Subway.
2. Institution of a trackless trolley route from Arborway to downtown Boston.

1. Green Line Restoration

This PMT Alternative would restore light rail service to the E Line between Heath Street and Arborway/Forest Hills station (see Figure G-48). The alignment would generally be the same as it was prior to the 1985 shutdown, except that cars would terminate at a new off-street loop at Forest Hills Station. (The right of way for this loop was constructed as part of the Southwest Corridor project, but has not had rails or a power system installed.) Bus Route 39 would be discontinued.

2. Arborway Trackless Trolley

As an alternative to restoring the Green Line, the PMT also examined a trackless trolley line from Arborway to Park Street. From Arborway/Forest Hills, the trackless trolley would follow the alignment of the Green Line tracks as far as the corner of Ruggles Street and Huntington Avenue. (The Green Line would continue to run as far as Heath Street, so the trackless trolley would offer parallel service between Heath and Ruggles.) The trackless trolley route then turn right on Ruggles Street and follow the route of bus 43 through the South End along Tremont Street and around Boston Common to Park Street (see Figure G-49). Route 43 would then be subsumed by the trackless trolley and Route 39 would be discontinued.[45]

Station stops along South Street, Centre Street and Huntington Avenue would be roughly the same as under the Green Line restoration. There would be somewhat fewer stops than currently exist for bus routes 39 and 43. Removing selected stops improves the running time of the service which has been estimated to be 32-35 minutes from Forest Hills to Park Street in the morning peak period. The fare structure assumed for the PMT would be the same as a local bus.[46] Headways would be five minutes during peak hours.

Ridership Impacts

The PMT forecasts indicate that with service re-instituted to Arborway/Forest Hills, the E Line would carry 36,160 weekday riders (18,080 in each direction) in 2020. (This includes ridership on the segment currently in service as well as between Heath Street and Arborway.) Only 136 of these would be new transit riders. (See Table G-82.) The remainder would either be users of the portion of the E Line that is currently in operation or would be diverted from other MBTA services. The main source of diversions would be bus Route 39, which would be discontinued.

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[45] Since the trackless trolley would not serve Copley Square without a transfer, as bus 39 now does and as the Green Line restoration would, it may be desirable to retain the route in a limited service (every 15 minutes).

[46] Another possibility would be to have a local bus fare for surface only trips and a rapid transit fare for trips including a transfer to a subway line.

Figure G-48
Green Line Arborway Restoration

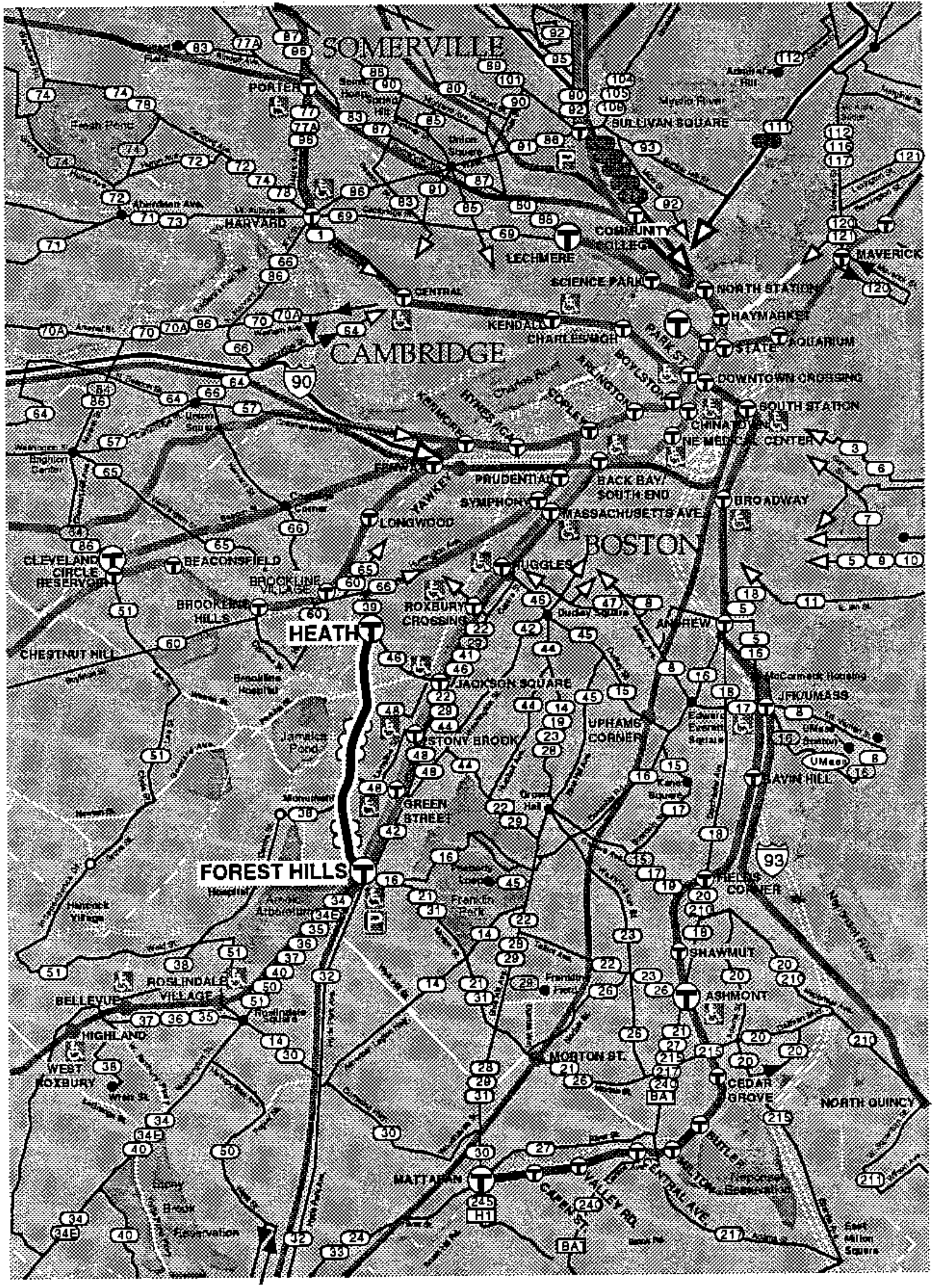

Figure G-49
Arborway Trackless Trolley

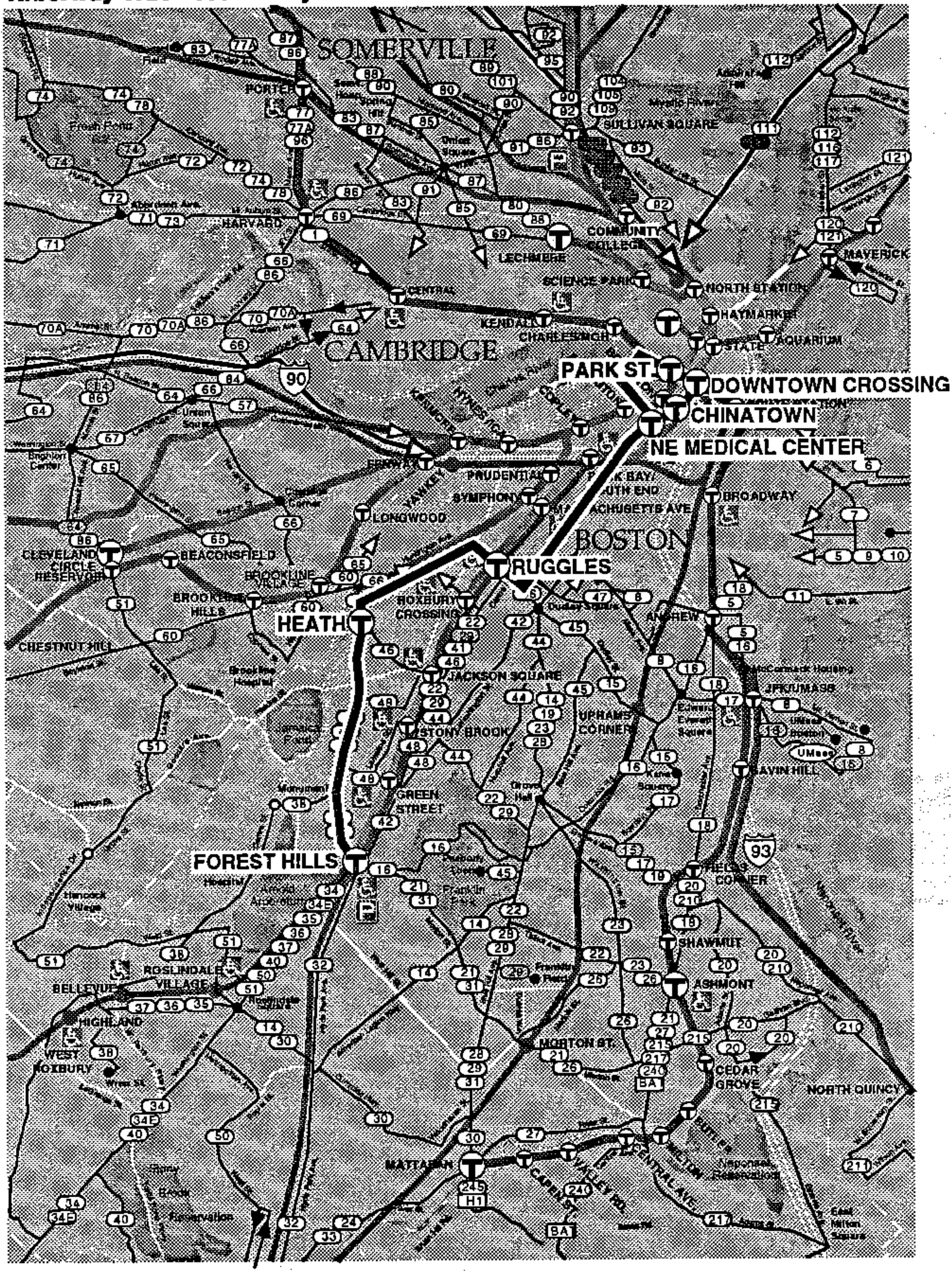

Table G-82
Ridership Impacts of Arborway Alternatives

	Total Ridership (Daily)	New Riders (Daily)	Annual Travel Time Savings (hours)
Green Line	36,160	136	691,560
Trackless Trolley	38,697	316	360,932

Travel time savings for the Green Line restoration would be relatively high at 691,560 hours per year. This places it at the top of the middle tier of projects, below the "megaprojects" such as the Inner Circumferential transit line, the Blue Line extensions and the North-South rail connector.

Forecasts for the Arborway Trackless Trolley indicate that the service would carry 38,697 weekday riders (19,349 in each direction) in 2020. Only 316 of these would be new transit riders. Like the Green Line restoration, the remainder would be people using other transit services including the present Green Line, the 39 bus and the 43 bus.

Travel time savings for the trackless trolley would be lower than for the Green Line, at 360,932 hours per year. This level of savings puts the trackless trolley in the mid-range of PMT projects.

Costs and Cost-Effectiveness

The estimated capital cost for restoration of E Line service to Forest Hills is $56.6 million. Of this, approximately $15 million is for reconstruction of fixed facilities, including tracks and power supply. The remainder is for purchase of low-floor light rail vehicles for the line.

Because most of the passengers on the extension would be base-case transit users, the cost per new transit rider would be the second-highest of any PMT project, at $417,400. (The only project with a higher cost in this measure would be a Foxborough commuter rail extension at $1,760,000.)

Extending all E Line trains from Heath Street to Forest Hills, combined with elimination of Route 39, would result in a net operating cost reduction of $1,484,000 per year. This would be the combined result of an increase of $5,038,000 in Green Line operating costs, but a reduction of $6,522,000 in bus operating costs.

Fare revenue would increase by $23,000 annually with the Green Line restoration. Even though there would be very few new transit riders, most of the diverted riders would be paying the rapid transit fare for the Green Line which is higher than the local bus fare for Route 39.

The cost for building the Arborway Trackless Trolley would range between $15 million and $27 million, depending on what type of vehicles would be used. Costs for the trolley infrastructure are in the range of $8 to $9 million. These are relatively low, given the length of the line, because the existing trolley poles and power system from Heath Street to Arborway could be partially reused for the trackless trolley. Thirty vehicles would be needed for the service given the five-minute headways. 40-foot trackless trolleys similar to the ones in use in Cambridge cost $210,000 each, while 60-foot articulated trolleys, like those proposed for use in the South Boston Transitway, cost roughly $630,000 each. This cost differential is the reason for the range in total project cost given above.

The capital cost per new weekday rider would be relatively high, between $42,600 and $85,400 depending on the vehicles, because of the small number of new trips produced by the project. It is comparable to several other fixed route projects such as the Blue Line extensions and the Green Line extension to Oak Square, and it is less than one-fourth the cost of the Green Line Arborway restoration. The capital cost per total rider would be the lowest of all the fixed route extensions ($388-698), less expensive even than express bus service from Route 128.

Like the Green Line restoration, the Arborway Trackless Trolley would result in a reduction of operating costs. The replacement of the two bus routes with the trackless trolley yields a net savings of $2.55 million annually: the trackless trolley would cost $5.5 million to operate, but bus Route 39 costs $6.5 million and Route 43 costs $1.5 million. If Route 39 were retained with reduced service, the savings would be less.[47]

Fare revenue would increase by $43,000 annually if the Arborway Trackless Trolley were built.

Table G-83
Costs and Revenues of Arborway Alternatives

	Operating Cost (Annual)	Fare Revenue (Annual)	Capital Cost	Capital Cost/ New Trip
Green Line	$-1.5m	$23,000	$56.6m	$417,400
Trackless Trolley	$-2.6m	$43,000	$15-27m	$42,600-85,400

Air Quality Impacts

The PMT method of calculating air quality benefits for each transit project takes into account only reductions in automobile use as a result of diversions to the project line. Because most of the riders on the E Line restoration and the Arborway Trackless Trolley would come from existing transit services rather than from automobiles, the PMT formulas indicate that air quality benefits would be negligible (a 0.0011 percent reduction in weekday emissions for the Green Line and 0.003 percent for the trackless trolley.)

The elimination of bus Route 39 would reduce bus miles by 1,875 on weekdays, 1,547 on Saturdays, and 1,310 on Sundays. This would produce additional air quality benefits not accounted for. The elimination of Route 43 would reduce bus miles by 472 miles on weekdays, 388 miles on Saturdays and 291 miles on Sundays.

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[47] With 15-minute daytime headways, 30 minutes in the evening and 20 minutes on weekends, annual savings would be reduced to $721,000.

Other Issues

Accessibility and Traffic Flow

As mentioned above, there are several complicating factors involved with service between Heath Street and Arborway, the primary one being accessibility requirements contained in the Americans with Disabilities Act. Accessibility has serious implications for the Green Line, even beyond the necessity to operate the service with low-floor vehicles. Current designs for low-floor cars maintain a height of 10 to 14 inches above the top of the track (similar to the height of the first step in the present Green Line vehicles). In order to have level access, the Green Line vehicles would have to stop at platforms the same height as the low floor. For the branches in street reservations this is not a serious problem, but for the E line beyond Brigham Circle, this is much more difficult since the tracks run unprotected in the middle of the street.

To provide accessibility for passengers in wheelchairs, the E Line tracks would have to be shifted from street centers to curbsides at least at stops. Weaving across lanes would have serious impacts on traffic flow. Relocating all of the trackage next to sidewalks would alleviate such traffic problems, but would eliminate all of the on-street parking along the route, including the busy commercial district of Jamaica Plain. Weaving tracks would present a serious hazard for bicyclists and an uncomfortable ride for automobiles.

The trackless trolley scheme would mitigate many of these problems. Low-floor trackless trolleys are more readily available than low-floor light rail cars, and thus the service could begin earlier. The flexibility of the trackless trolleys would allow them to flow with traffic more smoothly. The current tracks in the street could be removed, allowing for safer, smoother rides as well as reduced maintenance costs.

Differing Service Areas

Although the Green Line restoration and the Arborway Trackless Trolley both serve the area in Jamaica Plain formerly served by the E Line, they are not the same service. The Green Line restoration provides direct, no-transfer service to Huntington Avenue, into the Central Subway and out to Lechmere. The Trackless Trolley reaches Park Street as its final destination via the South End. People traveling to the South End from Jamaica Plain would get more direct service and people in the South End would receive a higher level of service than they now receive. However, Jamaica Plain residents who want to get to inner Huntington Avenue, Copley, Arlington, Boylston, or any of the Green Line stations north of Park Street would have to transfer. Transfers are now necessary for most of those destinations since the 39 bus terminates at Copley. If the 39 bus were also retained, current riders to those destinations would see relatively little degradation of service.

Conclusions

The standard PMT measures do not lead to clear conclusions about these projects. While both the Green Line restoration and the Arborway Trackless Trolley would apparently attract few new transit riders, the former would restore a one-vehicle ride to passengers traveling between outer E Line stops and Central Subway points east of Copley Station and the latter would offer a one-vehicle ride to Park Street and upgraded service to the South End. Both services would result in significant operating cost savings. The regional air quality improvement would be small, but within the E Line corridor, the improvement from reduction of diesel bus mileage could be significant.

It is recommended that improvements in this corridor be retained as a high priority project, but that these alternatives be evaluated further using criteria better suited to the unique characteristics of the corridor. In addition, it will be important to continue the ongoing dialogue with the Arborway community to ensure that the interests of all relevant parties are accounted for.

Red Line Extension to Mattapan

Existing Service

The Mattapan High Speed Trolley Line is a 2.6-mile light rail line, running from Ashmont station at the end of the Dorchester Branch of the Red Line to Mattapan Square. It is entirely on private right of way (a former commuter rail route) but has two at-grade road crossings. There are six intermediate stations between Ashmont and Mattapan, mostly serving residential neighborhoods in South Dorchester and Milton.

In 1989 counts, 65 percent of all riders on the High Speed Line transferred to or from the Red Line. The busiest two stations, Mattapan, and Central Avenue, accounted for 82 percent of all inbound boarding. Many of the passengers boarding at Mattapan transfer from feeder buses there, and transfer again at Ashmont to the Red Line. At present, there is no fare for most travel on the Mattapan Line, except that for inbound trips ending before Ashmont a 60-cent fare (equal to a local bus fare) applies.

Present headways on the Mattapan Line are five minutes in peak periods, eight minutes mid-day and 12 minutes at night. Rolling stock on the line consists of President's Conference Committee (PCC) cars built in the 1940s. Present peak schedules require six cars, all operated as single units. These are the remainder of a large fleet of cars used on the Green Line prior to the introduction of more modern light rail vehicles (LRVs).

The main reason for retention of PCC cars on the Mattapan Line is the lack of an on-line carhouse to maintain the electronic systems of LRVs. The PCC cars get light maintenance in the yard at Mattapan, but are trucked to other MBTA facilities for heavy repairs. It will not be cost-effective to operate the Mattapan Line indefinitely with the present cars, and a decision on their replacement will be needed in the near future.

PMT Alternative

The PMT analysis examined a possible replacement of the Mattapan High Speed Trolley Line with an extension of Red Line service from the present Ashmont terminal to Mattapan. New rapid transit stations would be located only at Mattapan, Central Avenue, and Butler Street. Present stations at Capen Street, Valley Road, Milton, and Cedar Grove would be discontinued.[48]

All Ashmont branch Red Line trains would run through to Mattapan instead of originating or terminating at Ashmont. Frequency would decrease on the Mattapan Line from 4 minute headways to 8 minute headways during the peak, but seating capacity would increase significantly because Red Line trains of four or six cars would replace the single unit PCC cars.

With the smaller number of stops, travel time between Mattapan and Ashmont would be reduced from 9 minutes to 5 minutes. Passengers traveling between points on the Mattapan extension and points on the present Red Line would experience additional time savings from

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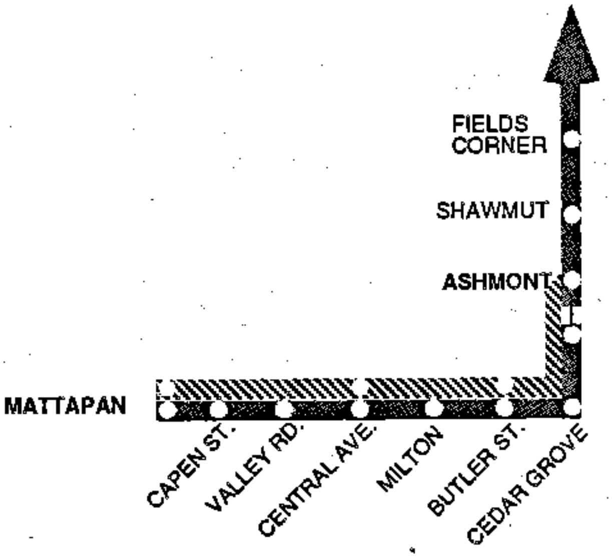
[48] CTPS counts in 1989 found that of 3,465 inbound daily riders on the High Speed Line, 548 or 15.8 percent used the stations that would be discontinued.

Figure G-50
Existing Mattapan High Speed Trolley and Potential Red Line Extension to Mattapan



elimination of the transfer at Ashmont. These time savings would be partly offset by the additional access time imposed on passengers whose current stations would be closed.

Ridership Impacts

An extension to Mattapan would serve 4,720 Red Line boardings per day in the year 2020. Of these, 1,260 would be new transit trips, and 3,460 would be diversions from other transit services. The largest share of transit diversions would come from the present Mattapan Line. Some of the remainder would come from MBTA local bus routes, especially Route 27, which parallels the High Speed Line between Mattapan and Ashmont.

The projection of 1,260 new weekday transit trips for the Mattapan Red Line extension is among the lowest among all of the rapid transit extensions being studied in the PMT, although it compares favorably with the commuter rail extensions and new express bus routes. Travel time savings for transit riders is estimated to be 338 hours per weekday, which is again the lowest for all of the rapid transit projects in the PMT..

Costs and Cost-Effectiveness

Among the changes needed for rapid transit conversion would be installation of signal and power distribution systems, elimination of grade crossings at Capen Street and Central Avenue, and construction of high-level platforms at stations being retained. Red Line cars could run on the existing tracks.

The most recent capital cost estimate for these improvements and the additional Red Line cars needed to serve the extension is $54.8 million. The average capital cost per new weekday transit rider would be $43,500. Of the rapid transit projects examined, only a Green Line extension to Medford Hillside or a Red Line-Blue Line connector would have a lower cost per new transit rider. The annual net cost of $27.34 per hour of travel time savings for the Red Line extension would be in the mid-range for all PMT projects.

Because of the age of the PCC cars, the MBTA will have to undertake some improvements to the Mattapan Line in any case to maintain service. As of the summer of 1993, all of the cars used on the line are receiving major overhauls at the Riverside carhouse, but this will not keep them running indefinitely. To run LRVs on the Mattapan Line, the power system would have to be upgraded and some arrangements would have to be made for routine maintenance. Costs for such improvements have not been estimated yet, but it is clear that a portion of the money which would be spent for a Red Line extension would have to be spent anyway just to maintain service.

The Americans with Disabilities Act requires that key stations on the Mattapan line be accessible to people in wheelchairs no later than 2020. The high platforms needed for a Red Line extension would solve the accessibility problem, while some other solution would be necessary if LRVs were used.[49]

Table G-84
Costs of Red Line to Mattapan Extension

Operating Cost (Annual)	Fare Revenue (Annual)	Capital Cost	Capital Cost/ New Trip
$1.3m	$0.24m	$54.8m	$43,490

The Red Line extension to Mattapan would result in an increase of $1.3 million in annual operating costs, compared to an increase of $24,400 in annual revenue. (The calculations assumed eight-minute peak-period headways and six-car trains.)

The majority of riders that would use a Mattapan Red Line extension now use the existing Red Line by transferring at Ashmont. Currently the Ashmont branch is served by a mix of four and six-car trains during peak periods. In the future, peak-period service will consist of all six-car trains. With time distribution similar to that of present ridership, new trips attracted by the extension should not cause serious crowding problems on the Red Line.

Operational Impacts

Operationally, an extension to Mattapan would have limited impact on the Red Line. The number of trains passing over the existing line would be unchanged. Increased loads could result in slightly longer dwell times, causing increased running times.

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[49] One plan is to shift the Boeing LRVs from the Green Line to the Mattapan Line as the new low-floor cars are purchased for the Green Line. Accessibility would be achieved through the construction of mini-high platforms in conjunction with adjustments to the entryways of the vehicles to allow for level access.

Through-routing of Red Line trains to Mattapan would eliminate the logistics problems entailed in maintaining a small isolated fleet of cars for the High Speed Line. It would also improve passenger flow on the platforms at Ashmont Station, where nearly one third of the Red Line passengers are now transferring to or from the High Speed Line.

Air Quality Impacts

A Red Line extension to Mattapan is projected to reduce regional emissions by 0.01 percent. This is the lowest reduction among all of the rapid transit and commuter rail extensions examined in the PMT. The capital cost per kilogram of VOC eliminated per weekday would be relatively low, at $5,141,700. (Only the Green Line to Medford Hillside, the Blue Line extension from Wonderland to Lynn, and the Blue Line-Red Line connector would be less costly in this measure among the rapid transit projects.)

Conclusions

A Red Line extension from Ashmont to Mattapan would attract fewer new riders than most of the other PMT projects examined to date. It would also be among the less expensive projects, with a capital cost of $54.8 million. Most passengers now using the Mattapan High Speed Line would experience faster travel times with a Red Line extension, and the majority would be relieved of one transfer per trip. Passengers not transferring to the Red Line would experience longer average wait times in peak hours.

Without a Red Line extension to Mattapan, substantial capital improvements will be required to maintain service on the High Speed Line. These will include upgrading the power system for compatibility with modern light rail vehicles, construction of an on-line vehicle maintenance facility, and modification of key stations for wheelchair accessibility.

It is important to note that the Red Line extension to Mattapan was examined by the MBTA in 1968. This plan was withdrawn because of opposition from the town of Milton, which would have lost all of its station stops. It is unknown whether local residents would be in favor of such an extension today.

The MBTA will have to make a significant investment in the Mattapan Line in the next five to ten years. At that time, it would be prudent to consider the Red Line extension as one of the options, given its benefits from an operational and systems standpoint.

Red Line Extension to Lexington

Existing Service

The MBTA Red Line consists of two branches starting from terminals at Ashmont Station in Dorchester and at Braintree Station. Joining just south of the Boston CBD, these routes continue through downtown Boston to Alewife Station in Cambridge, near the Arlington town line. Alewife Station is at the end of the expressway portion of state Route 2, and attracts riders from a wide area, including Arlington, Belmont, Lexington, and towns along Route 2 west of Route 128. The station has a 2,000-car parking garage and ramps to and from Route 2 to serve auto access trips. It is also served by six MBTA feeder bus routes that provide connections to Arlington, Bedford, Belmont, Burlington, Cambridge, Lexington, Winchester, and Woburn.

PMT Alternative

The project examined for the PMT would consist of an 8.5-mile extension of the Red Line from Alewife Station through Arlington and Lexington to Route 128 and ending at Hanscom Air Force Base near the Lexington/Bedford town line. It would follow the alignments of the abandoned Boston & Maine Railroad Lexington Branch and Hanscom Spur (see Figure G-51). The Lexington Branch right of way is owned by the MBTA, but is now used as a bicycle path (the Minuteman Bike Path) between Alewife and Bedford. The Hanscom Spur right of way is privately owned.

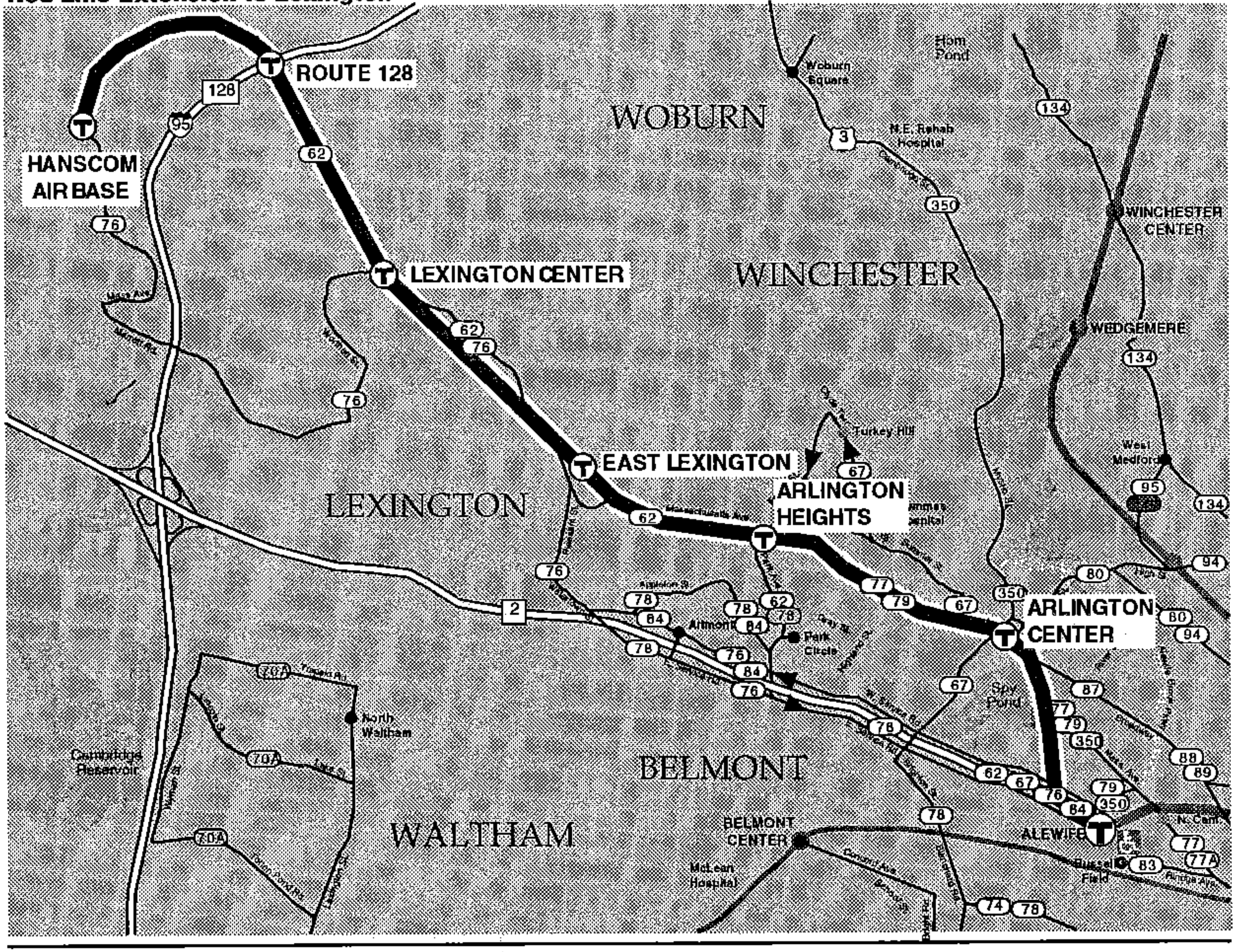
An extension of the Red Line to Arlington or Lexington from its then terminal at Harvard Square was examined by the Boston Transportation Planning Review (BTPR) in the early 1970s. The 1977 PMT included an extension from Harvard to Arlington Heights, and examined a further extension to Route 128. The present Red Line segment from Harvard to Alewife, completed, in 1985, would have been part of this extension. Plans for further construction beyond Alewife were not pursued because of strong opposition in the town of Arlington.

The extension examined in the present PMT analysis would include seven stations:

Station	Parking	Fare Zone
Arlington Center	—	2
Arlington Heights	100	2
East Lexington	250	2
Lexington Center	—	3
Route 128	1,000	3
Hanscom AFB	250	3

About half of all Red Line trains would operate along the extension, with the remainder continuing to terminate at Alewife. This would result in eight-minute headways at extension stations during peak periods and 12 minute headways during off-peak periods. The total travel time along the extension would be approximately 15 minutes.

Figure G-51
Red Line Extension to Lexington



Ridership Impacts

An extension to Route 128 in Lexington would serve 8,880 passenger boardings per day in the year 2020. Of these, only 2,380 would be new transit riders; 6,500, or 73 percent would be diverted from other transit services. Most of the diverted riders would otherwise access the Red Line at Alewife via automobile or feeder bus. There would also be some shifts from bus to Red Line for local travel within the extension corridor.

Both total ridership and new transit trips for a Lexington extension would be among the lowest for all rapid transit extensions examined. A Red Line extension to Mattapan would serve fewer riders, but would also be much shorter (2.5 miles) and much less costly to build and operate.

Costs and Cost-Effectiveness

A Lexington Red Line extension would have high capital cost, despite use of a former railroad right of way, because major reconstruction work would be required. The abandoned Lexington Branch had numerous at-grade road crossings. It also passed directly through the town centers of Arlington and Lexington. A Red Line extension along this alignment would have to be placed in either a cut or a subway for much of the way to eliminate the grade crossings and to avoid negative impacts in the town centers. The spur track from the Lexington Branch west of Route 128 into Hanscom AFB was recently sold by the Federal government to a developer and dismantled. Planned building construction on the right of way of this spur would conflict with use for a transit extension.

Assuming that two-thirds of the extension would need to be placed in a subway, the cost of track, tunnels, power and communications, stations, parking, and other associated facilities would be approximately $536.6 million. In addition, 30 new Red Line vehicles would be needed. At a cost of $1.8 million each, these would increase the total cost to $590.0 million.

Table G-85
Costs of a Red Line Extension to Lexington

Operating Cost (Annual)	Fare Revenue (Annual)	Capital Cost	Capital Cost/ New Trip
$9.5m	$0.7m	$590.0m	$248,330

Because the number of new trips that would be attracted would be low, the capital cost per new transit trip would be very high, at $248,330. This would be among the highest costs per new transit trip of any PMT project.

Because the extension would be long, operating costs would be high, at $9.5 million per year. Only $0.7 million would be generated in new farebox revenue, which would result in a farebox return of only seven percent.

Air Quality Impacts

A Red Line extension to Lexington would reduce regional emissions by 0.05 percent. This would be a moderate air quality benefit. The capital cost per kilogram of VOC eliminated per weekday would be $13.6 million. In this measure, the extension would be among the most expensive of all projects examined for the PMT.

Conclusions

A Red Line extension to Lexington would be expensive to construct ($590 million), expensive to operate ($9.5 million per year), and would attract relatively few new transit riders (2,380 new transit trips per weekday). The alignment for the extension is now used by the Minuteman Bike Path, which has been well utilized. Considering the high cost and low ridership of a Red Line extension, the right-of-way appears best suited to its present use.

New/Improved Express Bus Services

This section summarizes the results of the PMT analysis of improving express bus services to Boston and Cambridge. Projects include:

- New express bus routes.
- The construction of new park and ride lots on existing express bus routes.
- Improved integration of existing local and express routes in the Mass Pike corridor.

Existing Conditions

The Boston region has in place an extensive network of radial rapid transit and commuter rail lines. Much of the PMT analysis focused on these services, which provide comprehensive coverage in most of the area within Route 128. This section discusses possible express bus services that would complement the rail system in one of more of the following ways:

- fill gaps in the existing rail network within Route 128[50]
- be an alternative to a proposed rail extension
- provide parking for existing express bus services
- improve existing express services

The alternatives presented in the PMT are based on the premise that express bus services would be designed or revised to serve the same types of markets as rapid transit and commuter rail, which are also express-type services. These markets would include walk, drive, and, in some cases, feeder bus, access. This would differ from current operations in that most express bus routes are now designed primarily to serve local markets (i.e. walk access) only. The addition of new routes and the construction of park-and-ride lots along existing routes to attract passengers that live beyond walking distance of existing routes would increase the size of the markets served and increase ridership.

Current Express-Type Services

Most of the area within Route 128 is already served with one or more express-type services—rapid transit, commuter rail, and/or express bus (see Figure G-52). Existing MBTA express bus service operates to and from the North Shore, in the I-93 corridor, and along the Mass Pike. In general, the express bus services supplement, rather than compete with, commuter rail and rapid transit. The North Shore express routes are the oldest and, with the exception of Route 426, predate the MBTA. The I-93 and Mass Pike routes were instituted by the MBTA following the opening of the Mass Pike extension to Boston and the completion of I-93.

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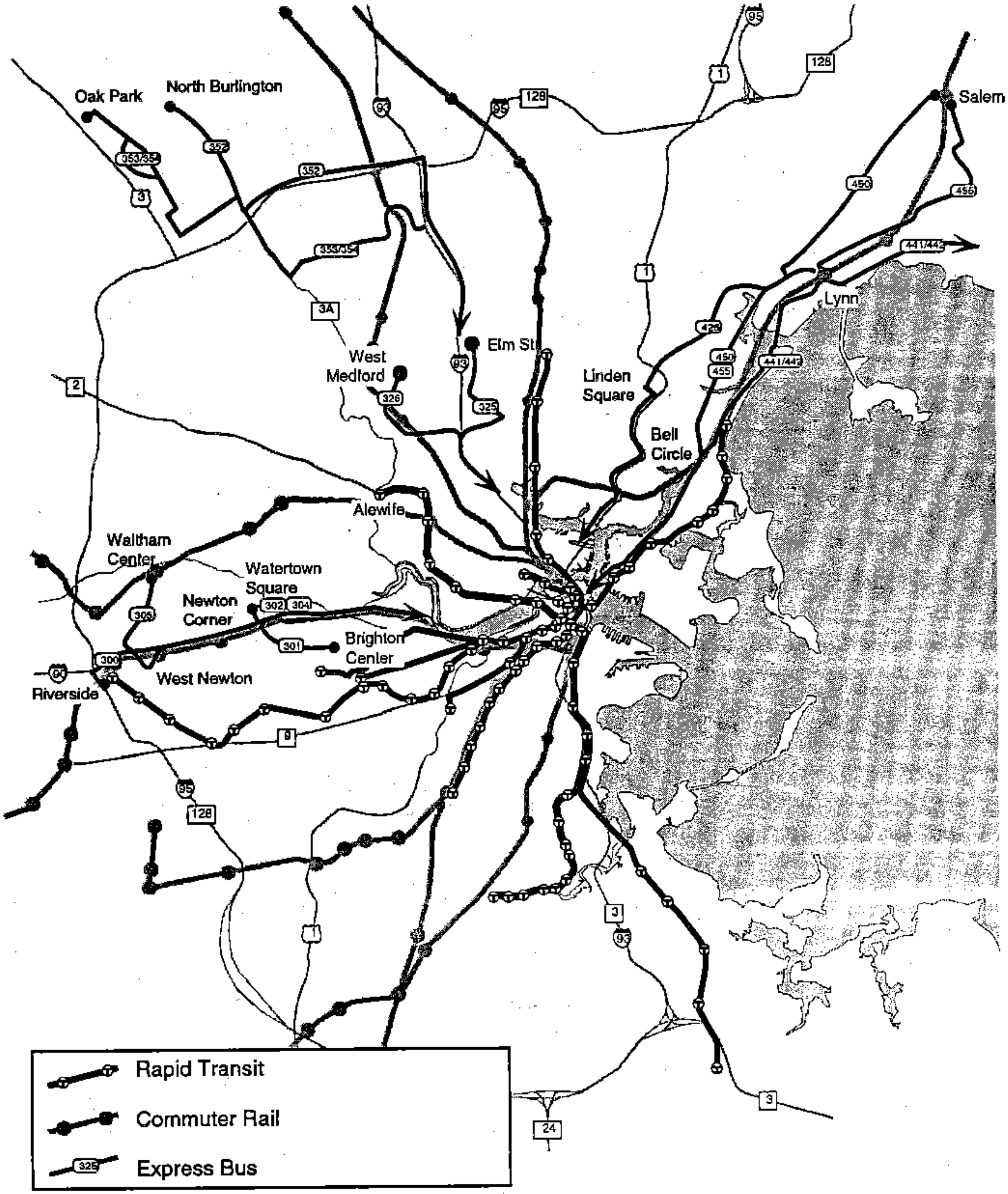
[50] Existing MBTA express bus service operates to and from communities along and within Route 128. From beyond Route 128, express bus services are provided by private carriers. Based on this unofficial boundary, MBTA express bus services from beyond Route 128 were not considered.

Figure G-52
Core-Oriented Rail and Express Bus Services



Gaps in Existing Coverage

As can be seen in Figure G-52, relatively few geographical areas within Route 128 are more than two miles from an express line (disregarding station and stop locations). The three major exceptions are:

(1) The Route 1 north corridor between Linden Square in Malden and Route 128 in Lynnfield (parts of Malden, Melrose, Revere, Saugus, Lynnfield, and Peabody).

(2) The Route 2 corridor between Alewife Station in Cambridge and Route 128 in Lexington (parts of Arlington, Belmont, Lexington, Waltham, and Lincoln). However, this corridor is served by local bus Routes 62 and 76, each of which provides relatively fast service to Alewife from sections of Lexington and Arlington that are close to Route 2.

(3) In Burlington, while there is existing express bus service, neither it, nor commuter rail, is convenient for those with origins north of Burlington that now use Route 3 to Route 128 to Route 2 or I-93.

PMT Alternatives

Potential new services would be designed to fill the gaps identified above, and to provide park and ride facilities on existing routes. There is also the potential to expand express coverage in Waltham and Newton by combining existing express and local routes.

New Express Bus Routes

New express routes and park-and-ride lots, which are shown in Figure G-53, would be as follows:

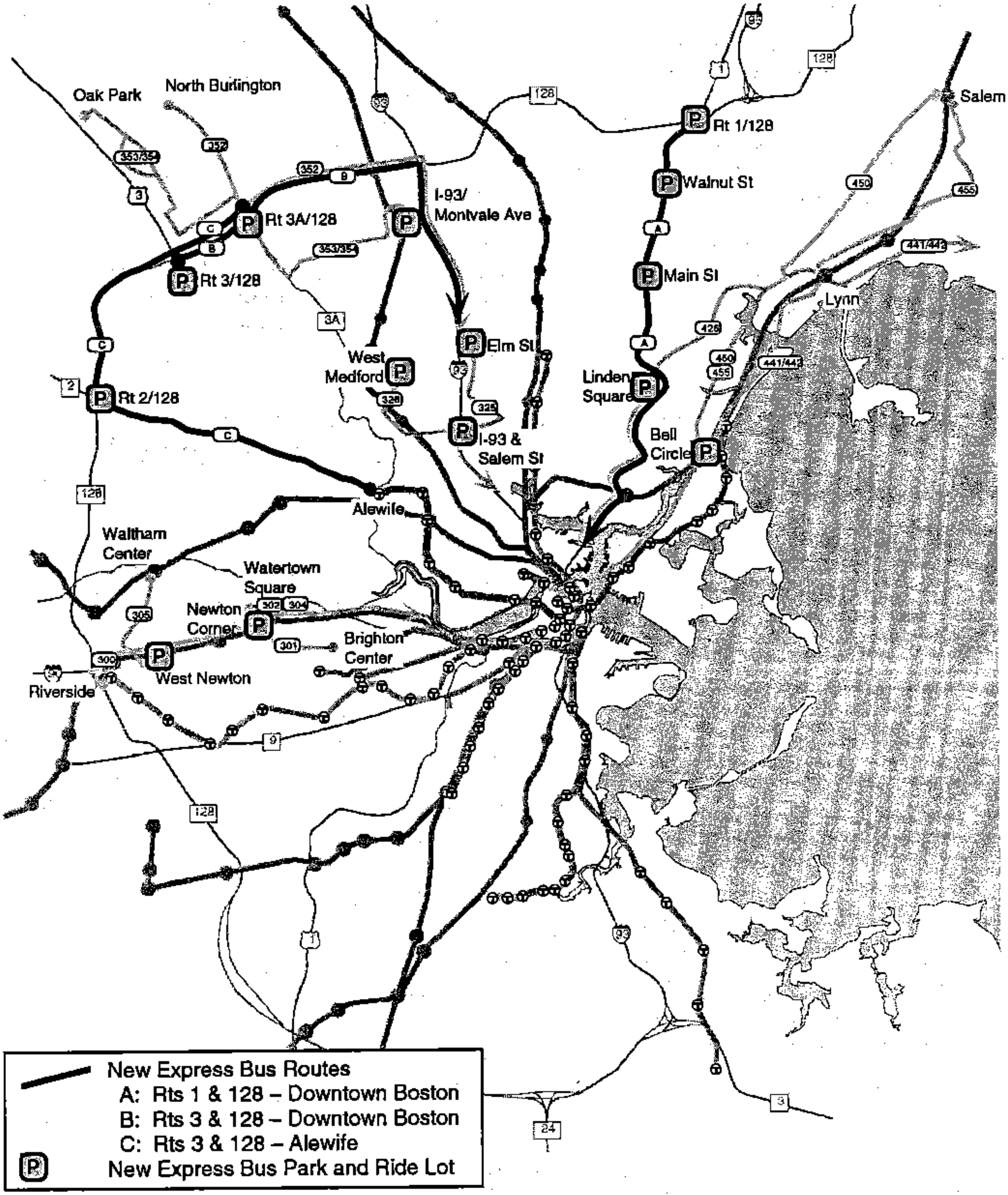
Lynnfield – Downtown Boston via Route 1

This express route would operate in the Route 1 corridor from the vicinity of the intersection of Routes 1, 128, and I-95 in Lynnfield. It would operate via Route 1 to the Central Artery to the Haymarket exit, and then via local streets to Downtown Crossing and Government Center. Park-and-ride facilities would be located at the beginning of the line in Lynnfield, and then at the following Route 1 interchanges: Walnut Street in North Saugus, Main Street in Saugus, and Route 60 in Revere. This route is labeled as "Route A" in Figure G-53.

Downtown Boston distribution would be via Haymarket Station, New Chardon Street, New Congress Street, Devonshire Street, Franklin Street, Washington Street, Court Street, Cambridge Street, and New Sudbury Street. Rapid transit connections would be provided with the Orange and Green lines at Haymarket Station, the Orange and Blue Lines at State Station, the Red and Orange lines at Downtown Crossing Station, and the Blue and Green Lines at Government Center Station.

During peak periods, service would operate at 15 minute headways. During off-peak periods, service would operate at 60 minute headways. Service would operate between 6:00 a.m. and 7:00 p.m.

Figure G-53
New Express Bus Routes



Burlington – Downtown Boston via Routes 128 and I-93

A Burlington – Downtown Boston route would be designed attract those commuters who now drive down Route 3 and those from sections of Lexington and Burlington outside of Route 128. Inbound, it would begin at a park-and-ride lot at the intersection of Routes 3 and 128, operate along Route 128 to a park-and-ride lot at the intersection of Routes 3A and 128, proceed along Route 128 and I-93 to a lot at Montvale Avenue and I-93, and then express to Boston via I-93. In Boston, it would provide the same distribution and rapid transit connections as the Lynnfield to Boston express route. This route is labeled as "Route B" in Figure G-53.

During peak periods, service would operate at 15 minute headways. During off-peak periods, service would operate at 60 minute headways. Service would operate between 6:00 a.m. and 7:00 p.m.

Burlington – Alewife via Routes 128 and 2

A Burlington – Alewife route would be designed to serve similar origins as the Burlington to Downtown Boston route but destinations in Cambridge and other locations accessible via the Red Line. It would start at a park-and-ride lot at Route 3A and 128, travel to the stop at the Route 3 and 128 park-and-ride lot, then to the Route 2 and 128 lot, and then travel express to Alewife Station. This route is labeled as "Route C" in Figure G-53.

During peak periods, service would operate at 15 minute headways. During off-peak periods, service would operate at 60 minute headways. Service would operate between 6:00 a.m. and 7:00 p.m.

New Park-and-Ride Facilities

In addition to the lots mentioned above for new express bus routes, new park-and-ride lots could be used to expand the markets of existing bus routes. Potential locations for new park-and-ride lots, and the routes they would serve, are as follows:

	Size	Routes Served
North Shore		
Bell Circle, Revere	100	441, 442, 450, 455
Route 60 at Route 1, Revere	50	426, A
Routes 1, 128, and I-95, Lynnfield	600	A
Walnut Street at Route 1, North Saugus	300	A
Main Street at Route 1, Saugus	200	A
Burlington and I-93 Routes		
Routes 3 and 128, Burlington	500	B, C
Routes 3A and 128, Burlington	550	352, B, C
Routes 2 and 128, Lexington	850	C
Playstead Road at Winthrop Street, Medford	150	326
Fellsway West at Elm Street, Medford	100	325
Salem Street at I-93, Medford	400	325, 326
Montvale Avenue at I-93, Woburn	950	B
Mass. Pike Routes		
Route 16 at Mass Pike, West Newton	150	305

(Note that a Newton Corner parking garage, which would serve existing express bus routes, was examined as an "intercept station." A garage at Newton Corner would serve a total demand of up to 890 spaces per weekday, which would consist of 2,170 total trips and approximately 950 new transit trips. See the "Intercept Stations along Major Highways" section for additional information.)

New express bus routes with park-and-ride lots located along major highways would serve the same purpose as rapid transit and commuter rail intercept lots along major highways: to divert automobile drivers to transit before they entered the core area. New lots in residential neighborhoods, such as those at the ends of Routes 325 and 326, would serve more limited local markets. These lots would be expected to serve mostly residents of the same towns as the routes they serve, but from areas beyond walking distance of bus stops.

Expanded Service Coverage for Mass Pike Express Routes

At present, MBTA express and local bus routes in the Waltham and Newton exist essentially as two separate systems. Express routes 300, 301, 302, 304, and 305 provide a high level of service, and are well utilized, while the local routes (52, 53, 54, 56, 58, and 59) provide low levels of service and are underutilized.

Much of the local service is already through-routed with Route 304.1 express service (Newton Corner–Downtown Boston). This includes nearly all trips on Routes 53 and 54, and most peak-period service on Routes 56 and 58. However, through-routed local trips are not marked as Boston trips and have a low level of visibility. As a result, many potential riders are likely not aware of the through-routed service; even for those that are, it can be difficult to know which trips are through-routed and which are not. Presumably for these reasons, the utilization of through-routed local service for trips to and from Boston is low—much lower than on the North Shore express routes or on Route 305. These problems could be solved by through-routing of all service on combinations of local and express routes and re-designating them as 300-series express routes. This would increase both the geographical reach of the express routes and the visibility of the services.

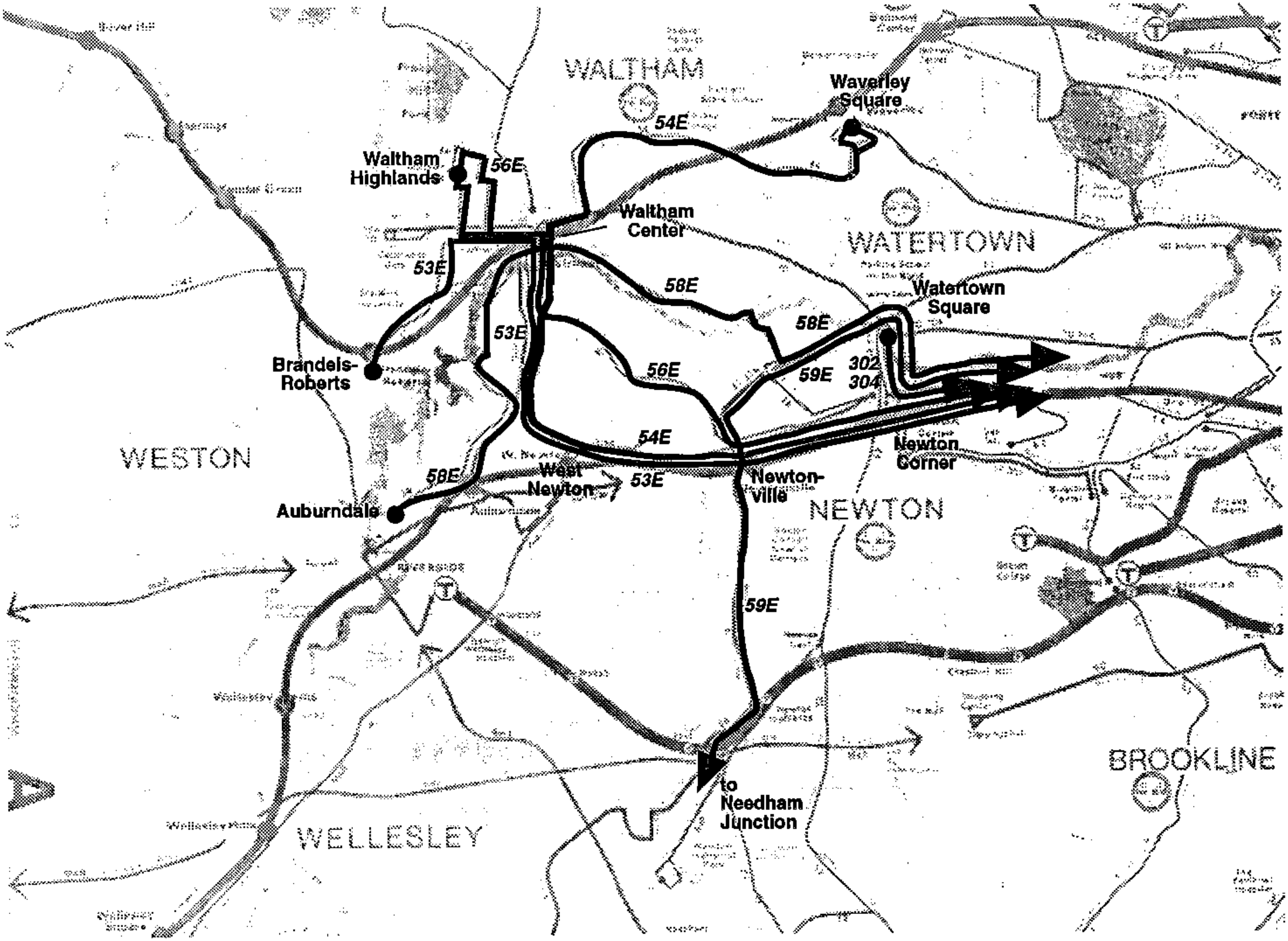
All six local routes—52, 53, 54, 56, 58, and 59—operate to Newton Corner or Watertown Square, and could be combined with Routes 302, 304, or 304A at these locations. These routes serve the following areas:

Route 52	Dedham Mall/Charles River Loop - Watertown Square
Route 53	Roberts - Newton Corner
Route 54	Waverley Square - Newton Corner
Route 56	Waltham Highlands - Newton Corner
Route 58	Auburndale - Newton Corner
Route 59	Needham Junction - Watertown Square

Prior analysis done as part of the West Corridor Bus Service Study indicated that a through-routing of Route 52 would not be warranted, but that others would be feasible and beneficial. Of the remaining five routes, four operate to Newton Corner (53, 54, 56, and 58) and one operates to Watertown Square (59). Local Newton Corner service would be combined with Route 304.1 service; local Watertown Square service could be combined with Route 302, 304.0, or 304.2.

For the purposes of this analysis, local routes combined with existing express service to create new express routes are designated by the local route number followed by an "E" (for express). For example, Route 53 combined with Route 304.1 would be designated as Route 53E. In more detail, these would be as follows (see Figure G-54):

Figure G-54
Improved Express Service in the Mass Pike Corridor



Route 53E: Brandeis/Roberts–Downtown Boston

This route would be a combination of Routes 53 and certain 304.1 trips. It would follow the same routing as existing through-routed 53/304.1 trips between Brandeis/Roberts and downtown Boston via Waltham Center, West Newton, Newtonville, and Newton Corner. The downtown Boston terminal, for this and all other routes described below, would be at Federal and Franklin Streets.

Route 54E: Waverley Square–Downtown Boston

Route 54E would be a combination of existing Route 54 and 304.1 trips. It would follow the same routing as existing through-routed 54/304.1 trips between Waverley Square and downtown Boston via Waltham Center, West Newton, Newtonville, and Newton Corner.

Route 56E: Waltham Highlands–Downtown Boston

This route would be a combination of Routes 56 and some 304.1 trips. It would follow the same routing as existing through-routed 56/304.1 trips between Waltham Highlands and downtown Boston via Waltham Center, Newtonville, and Newton Corner.

Route 58E: Auburndale–Downtown Boston

This route would be similar to a combination of existing Routes 58 and 304. The difference would be that a short segment of Route 58 between the intersection of Chapel Street and Watertown Street and Newton Corner would be re-routed through Watertown Square along Watertown Street and Galen Street. Between Auburndale and Chapel and Watertown Streets, Route 58E would follow the same alignment as Route 58. Between Watertown Square and downtown Boston, it would follow the same routing as Route 304.

Route 59E: Needham Junction–Copley Square/Downtown Boston

Route 59E would be a combination of Route 59 and Route 302/304.2. It would consist of a through-routing of Route 59 with Route 302 during the hours that 302 now operates, and with 304.2 during the mid-day when Route 302 does not operate.

Express Routes 53E, 54E, 56E, 58E, and 59E would replace existing service on Routes 53, 54, 56, 58, 59 and 304.1, but not 304.0.

On each of these routes, peak-period service would operate at 30-minute headways. During off-peak periods, service would operate at 60 minute headways. Service would operate between 6:00 a.m. and 7:00 p.m.

Ridership Impacts

All three of the new express bus routes examined would perform well, serving between 2,470 and 3,140 weekday trips each (see Table G-86). The construction of the park-and-ride lots that were examined in this section would attract up to 2,410 total trips, and 1,640 new transit trips, to existing routes. Improved coordination of local and express routes in the Mass Pike corridor would attract 520 total trips and 320 new transit trips.

Table G-86
Ridership Impacts of Express Bus Improvements/Expansion

	Total Trips	New Transit Trips
New Express Bus Routes		
Lynnfield – Downtown Boston via Route 1	2,470	1,940
Burlington – Downtown Boston via 128 and I-93	3,140	2,360
Burlington – Alewife via Routes 128 and 2	2,470	2,050
Park and Ride Facilities on Existing Routes	2,410	1,640
Expanded Coverage for Mass Pike Routes	520	320

In more detail, the impacts of the various types of express bus improvements would be as follows:

New Express Bus Routes

All three of the express bus routes examined would perform well. A new route between Burlington and Downtown Boston would carry the highest ridership, at 3,140 total trips and 2,360 new transit trips. The routes between Lynnfield and Downtown Boston and between Burlington and Alewife would each carry approximately 2,470 total trips, and 1,940 to 2,050 new transit trips. Virtually all of the riders (over 99 percent) on these routes would access them via automobile, with the highest ridership at lots at or near the intersections of major highways. Total ridership by park-and-ride lot at each route would be:

	Lynnfield - Boston (Rt A)	Burlington - Boston (Rt B)	Burlington - Alewife (Rt C)
Routes 1, 128, and I-95, Lynnfield	1,420	—	—
Walnut Street at Route 1, North Saugus	610	—	—
Main Street at Route 1, Saugus	440	—	—
Route 60 at Route 1, Revere	0	—	—
Routes 3 and 128, Burlington	—	670	320
Routes 3A and 128, Burlington	—	290	180
Routes 2 and 128, Lexington	—	—	1,970
Montvale Avenue at I-93, Woburn	—	2,180	—
Total	2,470	3,140	2,470

Projected ridership on each of these routes compares favorably with ridership on existing express routes, which in September 1992 ranged from 500 to 4,200. The three new routes examined herein differ from existing express services in that parking would be provided; as discussed in the next section, the lack of parking limits ridership on the existing routes.

Ridership levels on the Burlington to Alewife route are somewhat surprising, given that this route, unlike other express routes, would require most riders to transfer to the Red Line instead of taking them close to their final destinations. However, parking at bus park-and ride-lots would be free, so the cost of a Zone 2 express bus pass ($72/month) would be significantly less expensive than the combined cost of parking at Alewife and purchasing a Subway Pass ($115/month). In addition, express bus travel times would be only slightly longer than automobile travel times to Alewife. As a result, it appears that the $4.00

parking charge at Alewife (which is the highest in the system)[51] may act as a deterrent to ridership in this corridor, and that an express bus route between Burlington and Alewife could attract a significant amount of the ridership deterred by the Alewife parking fee.

New Park-and-Ride Facilities

The construction of new park-and-ride facilities along existing express bus routes would attract 2,410 new trips to express bus service. Of these, 1,640 would represent diversions from automobiles. The lots with the highest demand would be Route 128 at Route 3A in Burlington (which would be served by MBTA Route 352), and at I-93 at Salem Street in Medford, which would be served by MBTA Routes 325 and 326 (see Table G-87).

Table G-87
Demand for Parking Facilities along Existing Express Bus Routes

Location	Routes	Parking Demand	Weekday Transit Trips
Bell Circle, Revere	441, 442, 450, 455	40	100
Route 60 at Route 1, Revere	426	40	100
Routes 3A and 128, Burlington	352	310	740
Playstead Road at Winthrop Street, Medford	326	130	300
Fellsway West at Elm Street, Medford	325	50	120
Salem Street at I-93, Medford	325,326	350	820
Route 16 at Mass Pike, West Newton	305	100	230
Total		1,020	2,410

Note: Parking demand is in terms of the number of cars per weekday.

Expanded Service Coverage for Mass Pike Express Routes

The combination of existing local and express routes in the Mass Pike corridor would attract 520 new trips and 320 new transit trips. While these increases are relatively low, they would represent increases on existing services that could be achieved without incurring any capital costs.

Costs and Cost-Effectiveness

Improvements to express bus services would be relatively inexpensive to operate, and would generate high revenues relative to costs. Most of the options examined would also be inexpensive to implement (see Table G-88).

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[51] Parking fees at other rapid transit stations are $2.00, $2.25, or $2.50.

Table G-88
Cost-Effectiveness of Express Bus Improvements/Expansion

	Operating Cost (Annual)	Fare Revenue (Annual)	Capital Cost[52]	Capital Cost/ New Trip
New Express Bus Routes				
Lynnfield – Downtown Boston	$0.8m	$0.7m	$3.6m	$1,800
Burlington – Downtown Boston	$0.9m	$0.9m	$4.4m	$1,900
Burlington – Alewife	$0.5m	$0.5m	$3.1m	$1,500
Park and Ride Facilities on Existing Routes	Low	$0.5m	$2.6m	$1,600
Expanded Coverage for Mass Pike Routes	$0.1m	$0.1m	$0	$0

New Express Bus Routes

All three of the express bus routes would be inexpensive to implement and to operate. Capital costs for the three routes would range from $3.1 to $4.4 million, with the majority of costs split between the new buses required and parking facilities:

	Buses Req'd	Cost	Parking Spaces	Cost[53]
Lynnfield – Downtown Boston	6	$1.4m	1,100	$2.2m
Burlington – Downtown Boston	7	$1.6m	1,400	$2.8m
Burlington – Alewife	4	$0.9m	1,100	$2.2m

The capital cost per new transit rider would be $1,500 to $1,900. These costs are among the lowest among all PMT projects. Operating costs would increase by $0.5 to $0.9 million per year; most of these costs would be offset by new fare revenue. Resulting farebox return ratios would be high on all three routes: 87 percent on the Lynnfield to Boston route, 94 percent on the Burlington to Boston route, and 98 percent on the Burlington to Alewife route.

New Park-and-Ride Lots on Existing Routes

Specific locations for the new park and ride lots were not determined as part of the PMT analysis, and therefore the costs do not include land acquisition costs. However, it was assumed that all would be surface lots. On this basis, the construction costs for these lots would be approximately $2.6 million (the cost for each lot is shown in Table G-89).

The operating cost impacts of new park-and-ride lots would be very small, consisting only of maintenance. The PMT analysis assumed that the lots would be free, so that no parking revenue would be generated. However, the new bus riders attracted to the existing bus routes would increase fare revenue by $0.5 million per year.

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[52] Costs do not include land acquisition.

[53] Note that the parking costs do not include land acquisition. In some cases, multiple routes share a lot. In those cases, costs are split according to projected parking demand by route.

Table G-89
Costs and Revenues for Park and Ride Lots on Existing Express Bus Routes

	Operating Cost (Annual)	Fare Revenue (Annual)	Capital Cost[54]
Bell Circle, Revere	Low	$17,000	$200,000
Route 60 at Route 1, Revere	Low	$17,000	$100,000
Routes 3A and 128, Burlington	Low	$188,000	$700,000
Playstead Road at Winthrop Street, Medford	Low	$51,000	$300,000
Fellsway West at Elm Street, Medford	Low	$20,000	$200,000
Salem Street at I-93, Medford	Low	$138,000	$800,000
Route 16 at Mass Pike, West Newton	Low	$39,000	$300,000
Total	Low	$469,000	$2,600,000

Expanded Service Coverage for Mass Pike Express Routes

The through-routing of Mass Pike express routes with Waltham and Newton local routes could be accomplished with the same number of buses as are now deployed on those routes. Therefore, no capital costs would be involved. For the most part, the same amount of service as is currently being provided would be reallocated. In total, there would be a slight increase in the number of vehicle service hours provided that would increase operating costs by $83,000 per year. The service improvements would generate $120,000 per year in new fare revenue, which would result in a farebox return of 145 percent.

Air Quality Impacts

Each of the three express bus routes would reduce regional emissions by 0.03 to 0.04 percent. Combined, the reduction would be 0.11 percent. The capital cost per kilogram of VOC eliminated each weekday would be $107,600 to $137,300 (see Table G-90). The total air quality benefits would be moderate, but the cost of achieving these benefits would be very low—among the lowest of any of the PMT projects.

The provision of park-and-ride facilities along existing bus routes would reduce regional emissions by 0.03 percent. This would be relatively low, but the cost of achieving these reductions would be very low, at $98,700 per kilogram of VOC eliminated per weekday.

The through-routing of Mass Pike express routes with Waltham and Newton local routes would provide only a very small reduction in regional emissions (less than 0.01 percent), but at no cost.

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[54] Costs do not include land acquisition.

Table G-90
Air Quality Impacts of Express Bus Improvements/Expansion

	% Reduction Regional Emissions	Capital Cost/kg of VOC Elim/weekday
New Express Bus Routes		
Lynnfield – Downtown Boston	0.04%	$107,600
Burlington – Downtown Boston	0.04%	$137,300
Burlington – Alewife	0.03%	$112,400
Park and Ride Facilities on Existing Routes	0.03%	$98,700
Expanded Coverage for Mass Pike Routes	<0.01%	$0

Conclusions

The three express bus routes examined—Lynnfield to Downtown Boston, Burlington to Downtown Boston, and Burlington to Alewife—would each generate significant new transit ridership (1,940 to 2,360 per weekday), would have low capital and operating costs, and farebox recovery ratios of 87 percent and higher. Air quality benefits resulting from each individual route would be moderately low, but the combined impact of the three routes would be as high or higher than for many rail extensions (a 0.11 percent reduction in regional emissions).

The relatively high ridership on the three new express routes would be due to the provision of park-and-ride lots along each route. This would allow the new express bus routes to serve a wider market than most of the existing express bus routes, which now primarily serve riders starting from within in walking distance of the route. In the same manner that park-and-ride lots would attract riders to the new routes, they could also attract new riders to existing routes. Park-and-ride lots at seven new locations on the North Shore, in the I-93 corridor, and along the Mass Pike could attract 2,410 total trips and 1,640 new transit trips to existing routes. The capital cost to construct all of the lots would be $2.6 million, not including land acquisition costs. There would be little increase in operating costs (only maintenance of the lots), but the additional ridership would generate $0.5 million in new fare revenue.

Lastly, the combination of local express routes in the Mass Pike corridor would represent a more efficient use of existing resources. No capital expenditures would be required, and the additional fare revenue generated ($120,000 per year) would exceed the small increase in operating costs ($83,000 per year).

Route 128 Bus Service

This section summarizes the results of the PMT analysis of providing bus service on Route 128 between Beverly and Braintree.

Existing Conditions

The majority of public transit in the Boston region is a traditional hub-and-spoke network of commuter rail, bus, and rapid transit lines leading to downtown Boston. For suburb-to-suburb-commuting, which constitutes the majority of work trips made within and to the Boston area, transit has generally not been expanded due to difficulties in adequately serving dispersed trip origins and destinations. Development in the 1980s has increased the density of trip attractors (office, industrial and commercial employment) and trip producers (residential development) to the extent that it may be possible to institute successful suburb-to-suburb services.

Service Configuration for Route 128 Bus Service

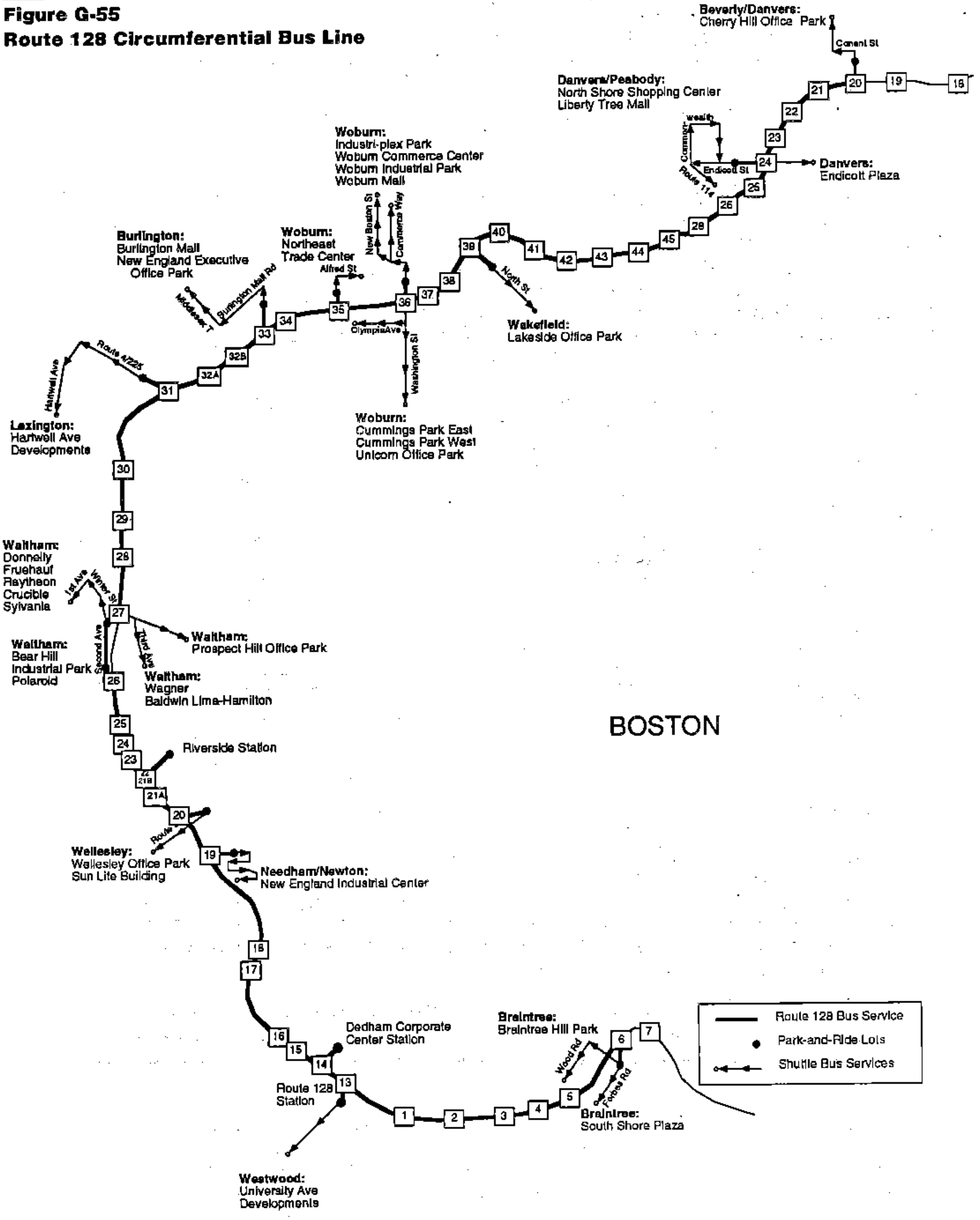
For a Route 128 bus service to be able to compete with automobile trips, it would need to be convenient, cost-competitive and have reasonable travel times. To make bus travel times reasonable, Route 128 service would need to stay on that highway to the greatest extent possible. Buses would leave Route 128 only to make stops at major interchanges. Local collection and distribution would be provided by park-and-ride lots located at these stops and by shuttle services to and from work sites. Most trips would involve two transfers. In the morning, the first would usually involve an automobile trip from home to the Route 128 bus at a stop at a park-and ride-lot. The second would be from the Route 128 bus to a shuttle to the final destination.

For the purposes of the PMT analysis, service was designed to serve the largest work trip attractors along the Route 128 corridor, with station sites selected to satisfy two criteria: (1) multiple major employment centers within a roughly 3.5 mile radius of the bus stop, and (2) the existence of local arterial roads that could provide good radial access. The second attribute is particularly important because it would minimize automobile travel time to and from the commuter's point of origin.

The trunk line service would operate 55.6 miles between Beverly and Braintree with 15 stops in 12 communities: one stop each in Beverly, Danvers, Wakefield, Burlington, Lexington, Newton, Wellesley, Needham, and Braintree, and two stops each in Dedham, Woburn and Waltham (see Figure G-55). Connections to other MBTA services could be made at Riverside (Green Line) and at the Dedham Corporate Center and Route 128 commuter rail stations.

Because employment density in the city of Waltham is very high, bus service would directly serve local developments between exits 26 and 27. The southbound alignment would be from Exit 27 on Route 128 to Second Avenue, Bear Hill Road, Main Street, Stow Street, Tavern Road and Route 20 back to Route 128 at Exit 26. This distance is approximately 2.5 miles. Major employment centers in this area include, among others, Polaroid and those in the Bear Hill Industrial Park.

Figure G-55
Route 128 Circumferential Bus Line



The service frequency would be 15 minutes during peak hours and 30 minutes in the off-peak Fares would be distance-based, ranging from 60¢ to $5.35. Parking at park-and-ride lots would be free except at rapid transit or commuter rail stations, where existing fees would be maintained.

Park-and-Ride Lots

Many potential Route 128 bus riders live in areas that do not have bus service. Therefore, park-and-ride lots would be necessary to provide for auto access to the route. For this analysis, in order to determine the maximum ridership potential, it was assumed that park-and-ride lots would be located at each interchange that would be served by a Route 128 bus route. Further, all park-and-ride lots would be located immediately adjacent to these interchanges (to minimize off ramp and on ramp travel time) unless otherwise noted. Parking for at least 100 cars would be provided and offered free of charge. Stops and park-and-ride lots would be located at the following locations:

Interchange	Radial Collector/Distributor	Community
Exit 20	Route 1A	Beverly
Exit 24	Endicott Street	Danvers
Exit 39	North Street	Wakefield
Exit 36	Washington Street	Woburn
Exit 35	Route 38	Woburn
Exit 33	Route 3A	Burlington
Exit 31	Route 4/225	Lexington
Exit 27	Winter Street	Waltham
Exit 26	Route 20	Waltham
Exit 22/21B	Riverside Station	Newton
Exit 20	Route 9	Wellesley
Exit 19	Highland Avenue	Needham
Exit 14	Dedham Corporate Center Station	Dedham
Exit 13	Route 128 Station	Dedham
Exit 6	Route 37	Braintree

Employer-Provided Shuttle Services

Shuttle services would provide connections between bus stops and work sites. For this purpose, it was assumed that shuttle services would operate at the same frequency as the Route 128 bus, with timed connections. This would involve sixteen separate shuttle services with run times of between 8 and 23 minutes. Shuttle bus trip lengths would range from approximately 1.5 miles in Wakefield to 3.5 miles in Lexington. The shuttle services would serve the following work sites:

1) To and from the vicinity of Exit 20 in Beverly via Route 1A, Conant Street to Cherry Hill Drive. This service is designed to serve the Cherry Hill Office Park in Beverly and Danvers. Large employers include Dynapert Incorporated, Eaton Corporation, and Emhart Industries, Inc.

2) To and from the vicinity of Exit 24 in Danvers via Endicott Street (west of Route 128), Commonwealth Avenue, Independence Way and Andover Street (Route 114)—this service is designed to serve developments in Danvers and Peabody including the Liberty Tree Mall and the North Shore Shopping Plaza. Among the area's largest employers are Demoulas'

Super Markets, Inc., K Mart Corporation, Sears Roebuck, May Department Stores Co., Century House of Peabody, Inc., and Essen Foods, Inc.

3) To and from the vicinity of Exit 24 in Danvers via Endicott Street (east of Route 128)—this service is designed to serve Endicott Plaza including GTE Corporation and the Visiting Nurse Association North Shore, Inc.

4) To and from the vicinity of Exit 39 in Wakefield via North Street—this service is designed to serve the Lakeside Office Park among other developments. Major employers include American Patriot Group, Inc., DAKA International, Inc., Sumaria Systems, Inc., and Systems Automation, Inc.

5) To and from the vicinity of Exit 36 in Woburn via Washington Street, New Industrial Road, Commerce Way and New Boston Street (north of Route 128) serving the Woburn Mall, Woburn Commerce Center, Woburn Industrial Park and Industri-plex among others. Major employers include Globe Data Systems, Inc., Steinbrecher Corp., Laidlaw, Inc., Lintec of America, Inc., Locke Manufacturing Co., Inc., the Savings Bank Life Insurance Council, and Loral Hycor Inc.

6) To and from the vicinity of Exit 36 in Woburn via Washington Street and Olympia Avenue (south of Route 128) serving Cummings Park West, Cummings Park East, and Unicorn Office Park. Major employers include Days Inns of America, Inc. and Marshalls, Inc.

7) To and from the vicinity of Exit 35 in Woburn via Route 38 to Alfred Street—this service is designed to serve the Northeast Trade Center among other developments.

8) To and from the vicinity of Exit 33 in Burlington via Route 3A, Burlington Mall Road and the Middlesex Turnpike—this service could potentially serve more than 300 employment sites, the largest of which include BayBank Middlesex, Hewlett-Packard Company, Rolm Company, May Department Stores Co., Digital Equipment Corporation, Wausau Mutual, the Lahey Clinic, M/A-COM, Inc., First National Bank of Boston, Xylogics, Inc., Jordan Marsh, and Sears Roebuck.

9) To and from the vicinity of Exit 31 in Lexington via Route 4/225 to Hartwell Avenue—this service is designed to primarily serve the many businesses on Hartwell Avenue. Major employers include Fisher Scientific Company, Litton Systems, Inc., McGraw-Hill, Inc., Private Health Care Systems, Rolm Company, Varian Associates, Inc., and MIT/Lincoln Laboratory.

10) To and from the vicinity of Exit 27 in Waltham via Winter Street to First and Second avenues —this service is designed to serve the area's major employers which include Automatic Data Processing, Inc., GTE Government Systems Corp., Cabot Corporation, and Polaroid Corporation.

11) To and from the vicinity of Exit 27 in Waltham via Totten Pond Road to Prospect Hill Lane, Third Avenue and Fourth Avenue—this service is designed primarily to serve Prospect Hill Office Park. Major employers include M/A-COM, Inc., Information Resources, Inc., and Pepsi-Cola.

12) To and from the vicinity of Exit 20 in Wellesley via Route 9—this service is designed to serve the Sun Life Building and Wellesley Office Park among other developments. Major employers include EG&G Inc., Wyatt Company, Unisys Corporation, Whitman & Howard, Inc., Eastman Kodak Company, and Sun Life of Canada U.S.

13) To and from the vicinity of Exit 19 in Needham (east of Route 128) via Highland Avenue—this service is designed to serve the industrial developments on Cabot Street, A and B Streets, First, Second and Third and Fourth Avenues. Major employers include Damon Corporation, Duracell Holdings Corporation, GWV Travel, GTE Corporation, Coca Cola Company, and Hearst Corporation.

14) To and from the vicinity of Exit 13 in Dedham—this service is designed to serve the University Avenue complex in Westwood. Major employers include LTX Corporation, HUB Mail Advertising Service, PB Diagnostic Systems, Inc., Alco Standard Corporation, MIB, Inc., and Faxon Company.

15) To and from the vicinity of Exit 6 in Braintree (south of Route 128)—this service is designed to serve Forbes Road developments and the South Shore Plaza. Major employers include Blue Cross Blue Shield, Flatley Company, and Community Habitat, Inc.

16) To and from the vicinity of Exit 6 in Braintree (north of Route 128)—this service is designed to serve Wood Road developments and the Braintree Hill Park. Major employers include Blue Cross Blue Shield, Haemonetics Corporation, Semline, Inc., and Johnson & Johnson.

Ridership Impacts

Bus service on Route 128 with park-and-ride lots and connecting shuttle services would carry approximately 3,470 trips per weekday. Virtually all of these would be new transit trips. Nearly all of the passengers (98 percent) would access the service by automobile, and most of the trips would be relatively long (an average of 13.5 miles). The relatively long trip length is a consequence of transfers being required at both ends, since the time and inconvenience of the transfers would be more of a disincentive for shorter trips than for longer ones.

Table G-91
Route 128 Bus Ridership

	Total Trips	New Transit Trips
Route 128 Circumferential Bus Service	3,470	3,470

With 3,470 new transit trips per weekday, Route 128 bus service would divert a high number of trips from automobiles to transit—more than any commuter rail project except the North Station - South Station Rail Link, and more than most rapid transit projects. However, a very large amount of new service would be needed to attract this ridership. At 55.6 miles, this route would be, by far, the longest in the MBTA system. In proportion to the amount of new service that would be provided, ridership would be low. The number of total passengers per vehicle service mile (VSM), and per vehicle service hour (VSH), would be 0.7 and 12.0 respectively. These figures are well below the MBTA's minimum service standards of 1.5 passengers per VSM and 30 passengers per VSH for bus service.

Further, it should be stressed that the full 3,470 trips could be attracted only if the bus service were supported by the park-and-ride lots and shuttle services. Few trips would be made by passengers that could walk to the bus at both ends. As a result, if Route 128 bus service were instituted without these supporting facilities and services, ridership would be extremely low.

Costs and Cost-Effectiveness

The institution of bus service along Route 128 would require a number of actions:

1) Construction of park-and-ride lots and associated stop facilities.
2) Purchase of buses.
3) Institution of connecting shuttle services.

The construction of park-and-ride lots and stop facilities and the purchase of the 24 buses needed to operate the service would cost $7.9 million (see Table G-92). The connecting shuttle services, if contracted for in the same manner as most existing suburban mini-bus services would not have an associated capital cost; capital costs instead would be built into the contract cost for the operation of the service. The $7.9 million total would result in a capital cost per new transit rider of $2,300. This would be one of the lowest such costs among PMT projects that would generate significant new ridership.

Table G-92
Cost-Effectiveness of Route 128 Bus Service

	Operating Cost (Annual)	Fare Revenue (Annual)	Capital Cost[55]	Capital Cost/ New Trip
Route 128 Circumferential Bus Service	$4.8m	$0.9m	$7.9m	$2,300

Because of the length of the route, and the level and span of service that would be provided, operating costs would be high, at $4.8 million per year. The new ridership, which would be low compared to the amount of new service provided, would generate $0.9 million in new fare revenue, or 17.9 percent of operating costs. This percentage is low, but is similar to the 21.5 percent ratio for all existing MBTA bus service combined.

Air Quality Impacts

Route 128 bus service would have a relatively large positive benefit on air quality, resulting in a reduction in regional emissions of 0.05 percent. The resulting capital cost per kilogram of VOC eliminated ($179,000) would be higher than those of most other PMT bus projects, but much lower than those of all PMT rail projects.

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[55] Costs do not include land acquisition.

Table G-93
Air Quality Impacts of Route 128 Bus Service

	% Reduction Regional Emissions	Capital Cost/kg of VOC Elim/weekday
Route 128 Circumferential Bus Service	0.05%	$178,700

Conclusions

Route 128 bus service could divert a relatively large number of automobile users—3,470 per weekday—to transit. Further, the capital cost of implementing the service ($7.9 million) would be low relative to the number of new riders that would be attracted.

However, there are also a large number of negatives to the service. First, it would be expensive to operate ($4.8 million per year), and be lightly utilized relative to the amount of service that would be provided. In terms of the number of passengers per vehicle service mile and per vehicle service hour, a Route 128 bus route would perform well below minimum MBTA standards.

Also, the PMT analysis assumed a cooperative effort whereby the MBTA would provide the Route 128 service and the connecting shuttle services would be locally financed and operated. This would require a major (and probably time-consuming) effort on the part of the MBTA and local cities, towns, developers, and/or transportation management agencies to set up connecting shuttle services. If, as an alternative, the MBTA were to finance and operate the connecting services, operating costs would be significantly higher.

Finally, it should be noted that the PMT analysis examined only one alternative for Route 128 bus service, and that this alternative was designed to provide service to the entire corridor. The resulting ridership projections indicate that there is a demand for service, but not for the level or extent of service that was examined. It is possible that more modest bus services could achieve much of the same ridership increases at lower costs. The examination of additional options was beyond the scope of the PMT analysis; subsequent work on Route 128 bus services should focus on this area.

Suburban Feeder Bus Services

This section summarizes the results of the PMT analysis of two alternatives for providing new feeder services to suburban rail transit stations. More specifically, three new routes to commuter rail stations in Needham and two new routes to the Green Line Riverside terminal in Newton were examined.

Time and budget constraints precluded analysis of new feeder bus services throughout the MBTA District. The alternatives discussed in this section were intended to be case studies, from which conclusions could be drawn as to the viability of new suburban feeder services in general.

Existing Conditions

The MBTA commuter rail system relies heavily on automobile access. In 1992 survey results, 52.5 percent of inbound commuter rail passengers drove or rode in cars that were parked at stations, and another 13.5 percent were dropped off. One reason for high auto use is that passengers originating beyond walking distance from stations have little other choice. About half of all stations are on MBTA or private-carrier bus routes, but at most of these stations there is little or no schedule coordination between buses and trains. Many of the bus routes run parallel with the rail lines, and serve few points beyond walking distance of the railroad stations.

The town of Needham is representative of communities served by the MBTA commuter rail system. It is the outermost town on the Needham Line. There are four stations in the town, at Needham Heights, Needham Center, Needham Junction, and Hersey (formerly Bird's Hill). Service runs on an irregular headway, with 17 round trips on weekdays and nine on Saturdays. Mid-day trains and the first morning round trip terminate at Needham Junction; all others run through to Needham Heights.

MBTA bus Route 59 (Needham Junction to Watertown Square) serves all Needham commuter rail stations except Hersey. As in most towns, rail and bus service in Needham developed independently, with little schedule coordination. Connections have improved as the result of bus schedule adjustments made in 1989, but are still only fair. Two of the five inbound AM peak trains have bus connections at Needham Junction five minutes or less before train time. A third trip has a 14-minute connection. Outbound, one PM peak trip has a one-minute scheduled bus connection. The other four trips have bus connections nine to 15 minutes after train arrival.

According to the 1992 commuter rail survey, only seven passengers a day transferred from bus to train at Needham Junction, and none transferred at the other stations. Ridechecks conducted on Route 59 in September 1992 confirm that there is little bus boarding and alighting activity that could be train related.

Even with much better schedule coordination, it is doubtful if transfers between Route 59 and Needham trains would increase significantly. The majority of stops on Route 59 within Needham are less than half a mile from a railroad station. From these stops, the combined waiting and riding time for a bus and connecting time at the transfer point would save little or no time compared to walking.

Route 59 also connects at Newton Highlands with the D Branch of the Green Line. Peak running time from Newton Highlands to Park Street on the Green Line is typically 30 to 35 minutes. This compares to 42 minutes from Needham Junction to South Station by train. The Green Line also runs on five-minute peak headways, and has a round-trip full fare of $2.85, compared to $4.50 for the train.

Because Route 59 is poorly suited to serve as a commuter rail feeder, the PMT analysis examined a network of new dedicated feeder routes to the Needham commuter rail stations. These are discussed below.

The outer half of the Green Line D Branch (a former commuter rail line) has little feeder service. Only two of the seven stations in Newton are served directly by MBTA local bus routes. The other five have well patronized parking lots. Parking capacities range from 54 to 1,128 cars per station, with the largest lot being at the Riverside terminal.

Of the seven Newton stations, Riverside has the greatest need for additional access options. It is the outer terminal for MBTA express bus Route 300 to downtown Boston as well as for the D Line. Surveys conducted in 1986 for the West Bus Service Study found that 76.4 percent of Route 300 riders parked at Riverside, and that another 7.4 percent were dropped off. On a typical weekday, at least 850 of the present 1,128 parking spaces are used. A planned re-design of the track and platform layout at Riverside will reduce parking capacity to 928. Most future ridership growth will therefore have to occur among passengers using access modes other than parking.

PMT Alternative

For the PMT analysis, two suburban feeder service alternatives were examined:

1. Feeder Bus to Commuter Rail in Needham.
2. Feeder Bus to Green Line at Riverside.

1. Feeder Bus to Commuter Rail In Needham

The PMT analysis examined a network of three new feeder bus routes for the Needham commuter rail stations. The following criteria were used in designing the routes

- Each route should primarily serve residential areas at least one half mile from any railroad station

- Each route should follow a reasonably direct path, to provide running times comparable to auto travel.

- Operation should be limited, to the extent possible, to streets customarily used for through traffic, or others where bus or minibus service has been allowed in the past, to minimize objections from residents not using the service.

- Routes should be short enough to allow one vehicle to provide all service on each route, with adequate allowances for delays and layovers.

It was also assumed that Needham train schedules would be revised to provide uniform 30-minute peak and hourly off-peak headways. These constraints led to the design of three routes, shown on Figure G-56. These were:

1) Central Avenue at Route 128 to Needham Center, via Central Avenue and Great Plain Avenue (extended to Needham Junction via Chestnut Street when connecting with trains that terminate at Needham Junction). Return via Chapel Street, Highland Avenue, Gould Street and Central Avenue. Above routing to be used in a.m. Service in p.m. to run toward station via reverse of a.m. outbound route, returning via reverse of a.m. inbound route.

2) Stockdale Road and Great Plain Avenue to Needham Junction, via Stockdale, Alden, and Carol Roads, Great Plain Avenue, Central Avenue, Marked Tree Road, High Rock Street, and Chestnut Street. Return via Chestnut Street, Great Plain Avenue. Above routing to be used in a.m. Service in p.m. to run toward station via reverse of a.m. outbound route, returning via reverse of a.m. inbound route.

3) Highland Avenue at Second Avenue to Hersey Station, via Highland Avenue, Hunting Road, Paul Revere Road, Falcon Street, Washington Avenue, and Great Plain Avenue. Return via Broad Meadow Road, Greendale Avenue, Hunting Road and Highland Avenue. Above routing to be used in a.m. Service in p.m. to run toward station via reverse of a.m. outbound route, returning via reverse of a.m. inbound route.

For purposes of analysis, it was assumed that the average end-to-end speed for each route would be 15 miles per hour. (This is comparable to the performance of the now-suspended Needham mini-bus system.) This would allow one bus on each route to make a round trip reliably in under 30 minutes.

Buses on each route would run on 30-minute headways during weekday peak hours. They would be scheduled to arrive at railroad stations five minutes before train departure in a.m. hours. In p.m. hours, buses would leave five minutes after scheduled train arrival if trains were on time, but would wait for late trains if necessary.

2. Feeder Bus to Green Line at Riverside

The PMT analysis examined several possible feeder routes to Riverside Station. After preliminary analysis of the demand potential along these routes, two were selected for more detailed study. These routes, shown in Figure G-57, were:

1) South Sudbury to Riverside via Wayland and Weston, on Routes 20 and 128.

2) Shopper's World, Framingham to Riverside via Natick and Wellesley on Routes 9 and 16.

Each route would have 30-minute headways inbound from 7:00 to 10:00 a.m. and outbound from 3:00 to 7:00 p.m. on weekdays.

At present, Route 20 bus service consists of one weekday round trip between Northborough and Boston. The Route 9 corridor is served by seven round trips a day between Worcester and Boston. Both routes are operated by private carriers, with funding from the MBTA/EOTC Interdistrict Transportation Service program. Both routes are poorly patronized, but the corridors they serve have more demand potential than this implies.

Figure G-56
Potential New Feeder Bus Routes to Needham Commuter Rail

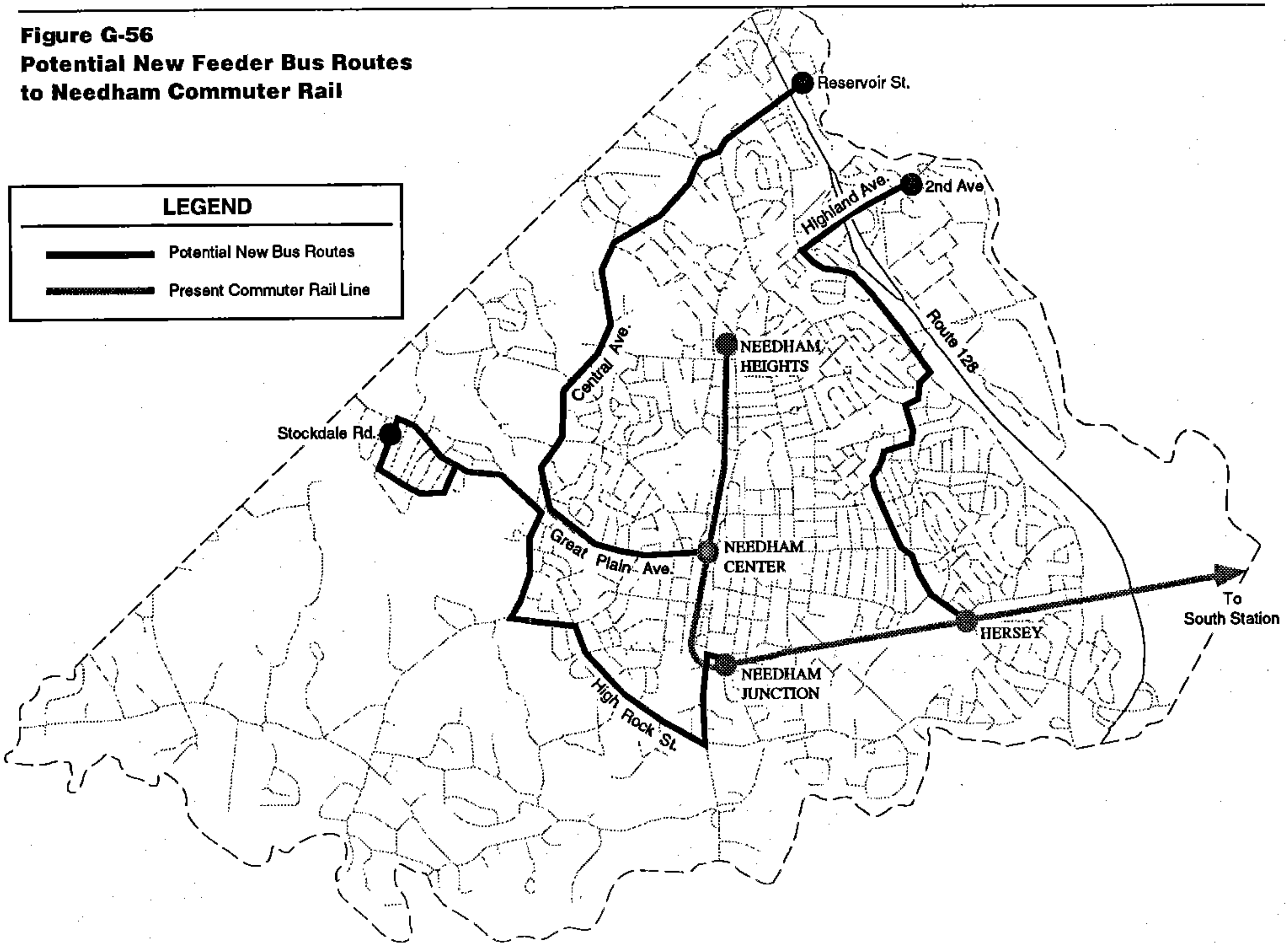
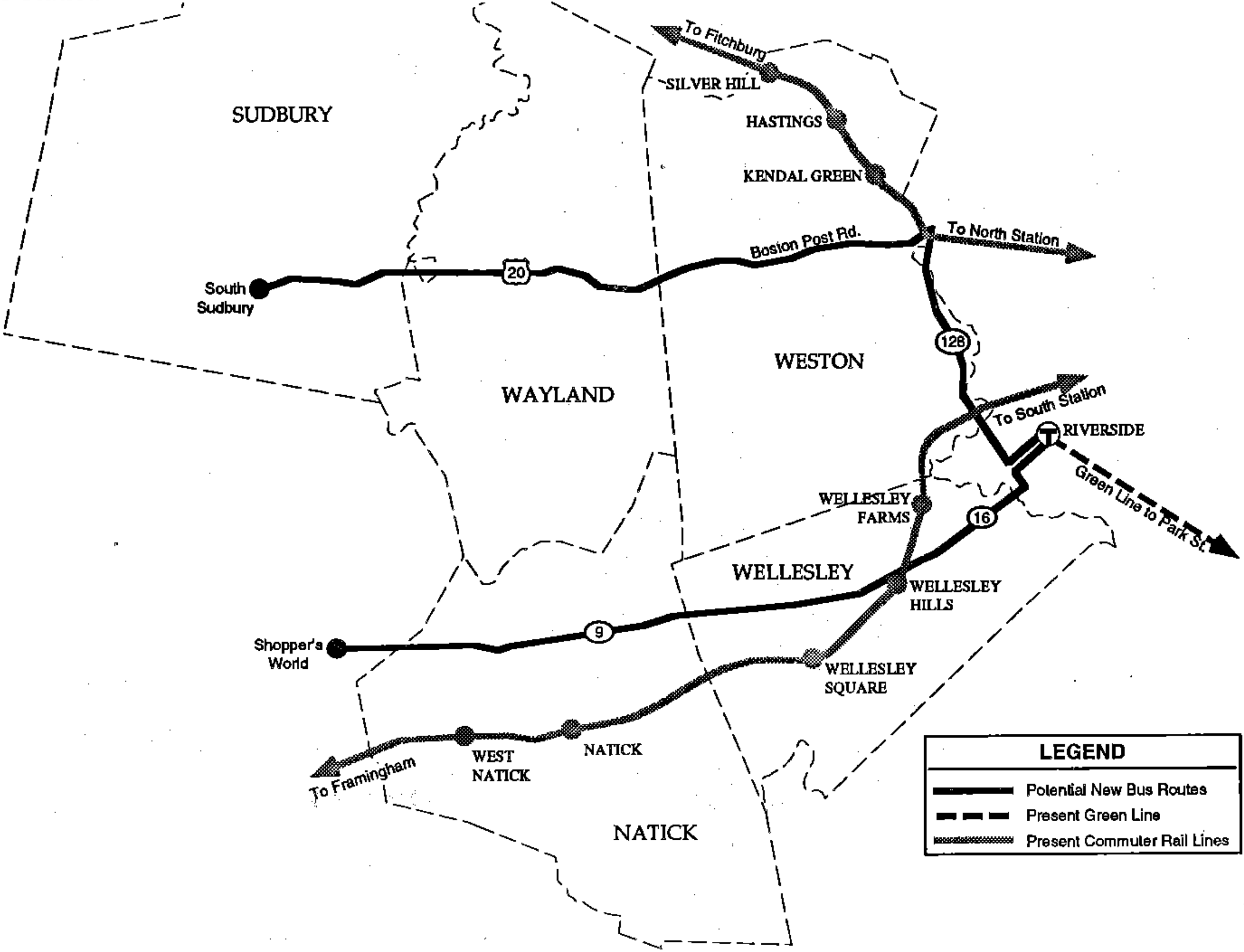


Figure G-57
Potential New Feeder Bus Routes
to Riverside Station



Ridership Impacts

The demand forecasts indicate that the Needham feeder bus network described above would be used by 340 riders per weekday (170 in each direction). All of these riders would use the commuter rail line even if the bus service were not provided, but would use other means of access to the stations.

The two Riverside feeder routes described above would be used by a combined total of 690 riders per weekday (345 round trips). Of these riders, 620 would use the Shopper's World route and only 70 would use the South Sudbury route. The total would include 490 new transit riders and 200 riders diverted from other transit services or from other access modes to Riverside.

Table G-94
Ridership Impacts of Suburban Feeder Bus Services

	Total Trips	New Transit Trips	Travel Time Savings (hr/yr)
Needham Routes	340	0	0
Riverside Routes	690	490	3,250

Costs and Cost-Effectiveness

The estimated capital cost for the Needham feeder bus system is $60,000. This represents the purchase cost of three vans. This would be an average of $176 per total weekday rider, which is the lowest cost of any PMT project requiring capital investment. Since the forecasts show no new transit riders, a cost per new transit rider cannot be calculated for this project. The annual operating cost of the system would be $113,000 if the system was operated by a private carrier, at a fixed price of $25 per vehicle hour. (This is based on the costs of MBTA Suburban Transportation Program systems in Burlington and Lexington.)

The standard analysis format for calculating revenue for PMT projects includes only fares from new transit riders, because of uncertainty in calculating revenue changes for old riders. All riders of Needham feeder bus service were projected to be base-case rail users, so no revenue impact was attributed to the service. In reality, passengers that switched to buses from walking or being dropped off would provide increased revenue. Passengers that switched to buses from paid parking would also provide increased revenue if round trip fares exceeded parking rates.

At present, fares for the various systems in the Suburban Transportation Program are set independently by the towns that sponsor them. MBTA passes are not valid on these routes. Using the Burlington fare structure of 75 cents for adults, 60 cents for students, and 35 cents for senior citizens, and the current ridership mix on the Needham Branch, the average fare would be 73 cents, and annual revenue would total $62,435.

The present parking fee at all stations in Needham is $1.00 per day. In the 1992 survey, 37 percent of all passengers using Needham stations drove and parked. If diversions to feeder buses were proportional from all current access modes, there would be a parking revenue loss

Table G-95
Costs of Suburban Feeder Bus Services

	Operating Cost (Annual)	Fare Revenue (Annual)	Capital Cost	Capital Cost/ New Trip	Cost/ Pass. Hr. Saved
Needham Routes	$0.1m	0	$0.01m	NA	NA
Riverside Routes	$0.8m	$0.1m	$1.3m	$2,755	$237.40

of $7,900 per year, leaving a net revenue gain of $54,535. This would result in an increase of $58,465 in the annual operating deficit.

Revenue would be much lower if the MBTA fare structure were used and MBTA passes were accepted on the buses. At current fare levels, the one-way adult cash fare for the feeder buses would be 60 cents, but most riders would pay less. The 1992 commuter rail survey showed that 12 percent of the passengers using the four Needham commuter rail stations paid full adult cash fares, and 18 percent used multiple-ride tickets. Another nine percent paid reduced fares for elderly, handicapped, children, or pupils. The greatest number (60 percent) used monthly passes. The Zone 2 passes required at Needham stations are valid on all MBTA bus routes, so no additional revenue would be generated by pass holders using Needham feeder buses. If the distribution of fares among bus riders were similar to that of all Needham train riders, the average revenue per rider would be about 18 cents. Annual revenue would then be only $15,200 per year. After deducting losses in parking revenue calculated as above, the net revenue increase would be $7,300 and the net deficit increase would be $105,700.

The estimated capital cost for the two Riverside feeder bus routes is $1,350,000. This represents the cost to buy three full-size transit buses for each route. The cost for either route alone would be $675,000. Some additional expenses would be required to post signs at stops along the routes. These have not been calculated specifically, but would be insignificant compared to vehicle costs. Projected ridership is insufficient to require construction of shelters at any stops that do not already have them for the existing bus routes.

Given the low projected demand for the South Sudbury route, if it is to be run at all, it could be run with vans at a much lower cost. The capital cost per new weekday rider for the two routes combined would be $2,755. In this measure, the routes would be among the most cost-effective of all PMT projects.

The annual operating cost for the two routes was estimated at $799,000, or $399,500 for each route, but these are high-end estimates. These routes would most likely be operated by private carriers under contract with the MBTA. Operating costs for such carriers vary widely, but all have lower costs than the MBTA itself. In recent years, there have been many changes in the carriers serving communities west of Riverside. It cannot be determined at this time which carriers would be awarded the contracts, or what prices they would agree to. Therefore, the estimates used MBTA operating costs.

The demand analysis for Riverside feeder buses did not include specific fare assumptions. Present fares in the area to be served vary widely among services. For example, the one-way commuter rail fare from Framingham to Boston is $3.25, but for the average pass holder the cost per trip drops to $2.48. Parking fees add $1.00 per round trip, resulting in total one-way costs of $2.98 to $4.25. On the private carrier bus on Route 9, the fare from Framingham to Boston is $4.70 one way. Parking at Shopper's World is free.

A passenger driving to Riverside from anywhere in the corridor would pay $2.00 to park plus $2.85 for a cash-fare round trip to Boston on the Green Line. This would make a one-way cost of $2.43, excluding automobile operating expenses. With a pass, the average cost would drop to $2.10. A passenger driving to Riverside to take the express bus to Boston would pay $2.25 each way for an effective cost of $3.25 including parking. With a pass, this would drop to $2.71.

Like the other transit alternatives in the area, the two Riverside feeder routes would have zoned fares. With zone boundaries at town limits, each route would have three zones. Fares to Riverside of 50 cents, 75 cents, and $1.00 would make the single-ride cost to Boston using a combination of the new buses and MBTA Route 300 $2.75 to $3.25. This would make fares consistent with those on the Framingham commuter rail line and the present Route 20 bus line. At an average fare of 75 cents, revenue from new transit riders would total $330 per day, or $82,830 per year on the Shopper's World route. With MBTA operating costs, this would result in a revenue-to-cost ratio of 0.21. Results with private-carrier costs would be more favorable.

On the South Sudbury route, revenue from new transit riders would total only $37.00 per day, or $9,350 per year. With MBTA operating costs, this would result in a revenue-to-cost ratio of 0.02. Even the much lower operating costs of a private carrier would be insufficient to provide a reasonable cost recovery rate for this route.

Air Quality Impacts

The method used to calculate VMT reductions for all PMT projects is based on the number of new transit riders attracted. Since the analysis indicates that the Needham bus service would be used only by base-case rail riders that would change their access modes, no changes in auto travel are shown.

There would actually be some VMT reductions as a result of passengers shifting to buses from parking or being dropped off at stations. For a given access trip, the greatest amount of VMT is generated when the train passenger is dropped off by a vehicle that is operated from the passenger's origin to the station and back without serving any other purpose. All the Needham bus routes would be about three miles long. The maximum possible VMT reductions would occur if all bus passengers lived at the outer ends of the routes and would be driven to stations if buses were not provided. In that case, at the estimated demand level, the bus system would reduce weekday auto miles by 2,040. Regional emissions would be reduced by a negligible 0.003 percent. This is a high estimate, since some passengers would travel shorter distances, and some would use access modes other than drop-off if buses were not provided. (The 1992 survey results show that only 9.7 percent of all passengers using Needham train stations were dropped off.)

The two new feeder bus routes to Riverside described above would have relatively small air quality benefits. Regional emissions would be reduced by 0.01 percent. The Shopper's World route alone would account for most of this. Because the only capital costs for these routes would be purchase of vehicles, the capital cost per kilogram of weekday VOC eliminated would be among the lowest of all PMT projects examined, at $141,143. For the Shopper's World route alone, the cost would be about $78,300.

Conclusions

A new feeder bus network serving the Needham commuter rail stations would make train service more convenient for passengers that would use it anyway, but it would not attract new transit riders. Air quality improvements resulting from this service would be negligible. The capital and operating costs of a Needham bus network by itself would be relatively low. From an equity standpoint, however, it would be difficult for the MBTA to justify funding feeder bus service for Needham but not for other cities and towns on the commuter rail system. Therefore, it is not recommended that such service be included in the PMT.

A new feeder bus route to Riverside from Shopper's World via Route 9 would attract fewer new transit trips (420) than most of the rail projects examined for the PMT. The service would not require new investment in fixed facilities. Therefore, the capital costs per new rider and per kilogram of VOC eliminated would be among the lowest for all PMT projects. If ridership failed to reach targeted levels, the vehicles could be re-assigned elsewhere. It is recommended that this route be implemented on a trial basis.

Ridership projections for the South Sudbury-Riverside bus route indicate that demand would be insufficient to justify such a service. The Shopper's World route has a much higher probability of success, and should be tested first. It is not recommended that the South Sudbury route be tried unless the Shopper's World service proves to be much more successful than predicted.

Appendix H
Air Quality Methodology

Air quality impacts of transportation related projects are based on two components: emission rates and vehicle miles traveled (VMT). Emission rates are estimated using Environmental Protection Agency software called Mobile5A; VMT estimates are an output of the regional model described in Appendix E. This appendix describes the way these factors are developed and how they have been used for air quality analysis of PMT projects.

Major Components of Vehicle Emissions

Vehicle emissions are made up of both exhaust emissions and evaporative emissions (see Figure H-1). Exhaust emission is the by-product of burning gasoline or diesel fuel, and is dependent on operating mode (hot start, cold start, stabilized), the speed at which the engine is running, and the air temperature.

Figure H-1
Emission Components

Emission Component	Primarily a Function of...
Exhaust	Operating mode, speed, and air temperature.
Running Evaporative	Engine temperature, running time.
Resting Evaporative	Age of auto, condition of seals and gaskets.
Refueling Evaporative	Vapor recovery systems and programs.
All Evaporative	Air temperature, and fuel volatility

Evaporative emissions occur when the car is running, resting, and refueling. The amount of running evaporative emissions is a function of the temperature of the engine, which in turn depends on how long the car has been running. The amount of resting evaporative emission is dependent on the age of the car and condition of various seals and gaskets. Refueling emissions are controlled by vapor recovery devices used at filling stations. All evaporative emissions are also dependent on the volatility of the fuel and ambient temperature. The only pollutants in evaporative emission are volatile organic compounds (VOCs). The evaporative and exhaust emissions are combined into "emissions factors" or emission rates that are used in calculating changes in emission burden.

Transit projects that reduce VMT reduce vehicle emissions. Because exhaust emissions are dependent on speed and operating mode, and running evaporative emissions are dependent on length of trip (in time), *all VMT are not equal* with respect to emissions. The rate of exhaust emissions are higher at slower speeds and when the car is operating in cold start mode. Running loss evaporative rates are lower on short trips than they are on long trips. As the engine heats up there is more evaporative loss from the fuel tank, fuel lines, and engine.

Air Quality Analysis for PMT Projects

The PMT air quality analyses involved the use of average emission rates per vehicle miles of travel. As a result, the stated impacts do not fully consider the different emissions rates of each operating mode. However, as described below, the results are valid at the sketch planning level of detail used for the PMT and do provide for valid comparisons between projects.

Impact of Cold Starts

Transit trips that involve automobile access provide lesser air quality benefit than those which entirely involve transit and walking. All or much of the automobile access portion of the trip is in cold start mode; as a result, emission rates for these trips are higher than "normal."

The magnitude of the difference can be seen by comparing emission rates for drive access trips with emission rates for normal (Federal Test Procedure)[1] trips. As described above, Volatile Organic Compounds (VOCs) emission rates from transit drive access trips are higher than normal emission rates due to the fact that the vehicle is operating in cold start mode for most or all of the trip. However, this effect is partly mitigated because drive access trips are shorter than "normal" trips and therefore produce less running loss evaporative VOCs emission per mile. The combined effect of these two factors results in VOC factors that are on average 24 percent higher for transit access trips than "normal" factors.[2]

Because there are no running evaporative emissions associated with NOx and CO, the trip length has no effect on the emissions rate, and thus only operating mode (cold start, hot start, or stabilized) affects the emission factors. Cold start NOx rates are on average 25 percent higher, and CO rates are 143 percent higher for transit access trips than normal emission rates.

Rates of emissions should not be confused with emission reductions. The effect that these higher drive access emission rates have on the reductions of a specific project is completely dependent on the length of the transit trip.

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[1] Federal Test Procedures are a set of standard default values used in Mobile5A. Many FTP values can be adjusted for more specific analysis.

[2] Differences are based on Mobile5A factors for light duty gas vehicles in 1993. They assume a worst case scenario where the whole drive access trip would be in cold start mode. In addition, the VOC analysis assumes that the transit access trip is less than ten minutes.

Examples

Two examples shown below illustrate the impact that automobile access can have on short and long transit trips. For short transit trips, the emissions from an average drive access trip could significantly reduce any emission reduction due to new transit riders; for longer transit trips, the drive access emissions are small compared to the emission reduction due to the elimination of the corresponding auto trip.

Short Trip

A short walk-access transit trip that eliminates 7 miles of automobile travel would save 12.6 grams of VOC from being emitted:[3]

100% Auto Trip = 7 VMT * 1.8 grams of VOC per mile = 12.6 grams of VOC

100% Transit Trip = 0 grams of VOC

Reduction = 12.6 grams of VOC

If the transit trip includes a 3.75 mile automobile access trip, it would produce 10.9 grams of VOC, thereby reducing the savings to 1.7 grams, and negating most of the air quality benefit:

100% Auto Trip = 7 VMT * 1.8 grams of VOC per mile = 12.6 grams of VOC

Auto Access Trip = 3.75 miles * 2.91 grams of VOC per mile = 10.9 grams of VOC
Transit Trip = 0 grams of VOC
Total = 10.9 grams of VOC

Reduction = 1.7 grams of VOC

Long Trip

A long walk-access transit trip that reduced VMT by 25 miles would save 45.0 grams of VOC from being emitted:

100% Auto Trip = 25 VMT * 1.8 grams of VOC per mile = 45.0 grams of VOC

100% Transit Trip = 0 grams of VOC

Reduction = 45.0 grams of VOC

If the long transit trip includes a 3.75 mile automobile access trip, it would produce the same 10.9 grams of VOC as the auto access to the short trip. However, in this case, the transit trip would still provide significant air quality benefits—a reduction of 34.1 grams:

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[3] The calculations of emission assume an average speed of 35 miles per hour for the 1.8 grams/mile factor used for transit trip savings, and 24 miles per hour for the 2.91 grams/mile factor used in the calculation of drive access emissions. The drive access distance is an estimate of regional average distance driven to park and ride lots.

100% Auto Trip = 25 VMT * 1.8 grams of VOC per mile = 45.0 grams of VOC

Auto Access Trip = 3.75 miles * 2.91 grams of VOC per mile = 10.9 grams of VOC
Transit Trip = 0 grams of VOC
Total = 10.9 grams of VOC

Reduction = 34.1 grams of VOC

PMT alternatives were designed so that only relatively long trips would have parking facilities. With a few exceptions—express bus parking and the expansion of existing parking facilities at rapid transit stations—new parking facilities would be located along Route 128 or beyond. Therefore, while some of the emission reduction figures may be somewhat overstated, there are not any cases where automobile access to transit would negate the air quality benefits of the transit trip.

Appendix I
History of Mass Transit Planning in the Boston Region

The public transportation system of the Greater Boston area has a long and complex history. What today is an integrated, publicly owned and operated system, began as a number of private ventures, hoping to produce profits by capitalizing on the ever-growing demand for mobility.

Over the hundred years since the beginning of public involvement in the construction of mass transit facilities, planning for the public transportation system has proceeded in fits and starts. This chapter will examine the periodic planning efforts which have brought the Boston area to its current mass transit system made up of rapid transit, light rail and commuter rail lines (see Figure I-1). A study of the private investments and plans for streetcar lines and railroads would be very interesting, but it is beyond the scope of the present chapter.[1]

Establishment of the Boston Transit Commission and the Boston Elevated Railway

The first large scale planning effort for public transportation facilities in the Boston area occurred with the establishment of the Boston Transit Commission and the Boston Elevated Railway Company in 1894. Prior to that time, many miles of streetcar track had been laid, but this construction had been undertaken by private entrepreneurs, driven by market forces rather than a comprehensive plan. In the early 1890's, when the downtown area was severely congested with streetcar traffic, the City of Boston decided that the time had come to invest in rapid transit facilities, both elevated lines, which had been in use for several years in New York and Chicago, as well as subways, which had not yet been tried anywhere in North America. The Massachusetts legislature passed an act in 1894 to "Incorporate the Boston Elevated Railway Company and to Promote Rapid Transit in the City of Boston and Vicinity."[2] This act called for three elevated and three subway lines to be constructed which would form the basis for a rapid transit network. Only two of these six projects were constructed in a way similar to the proposals described in the 1894 act, namely the Tremont

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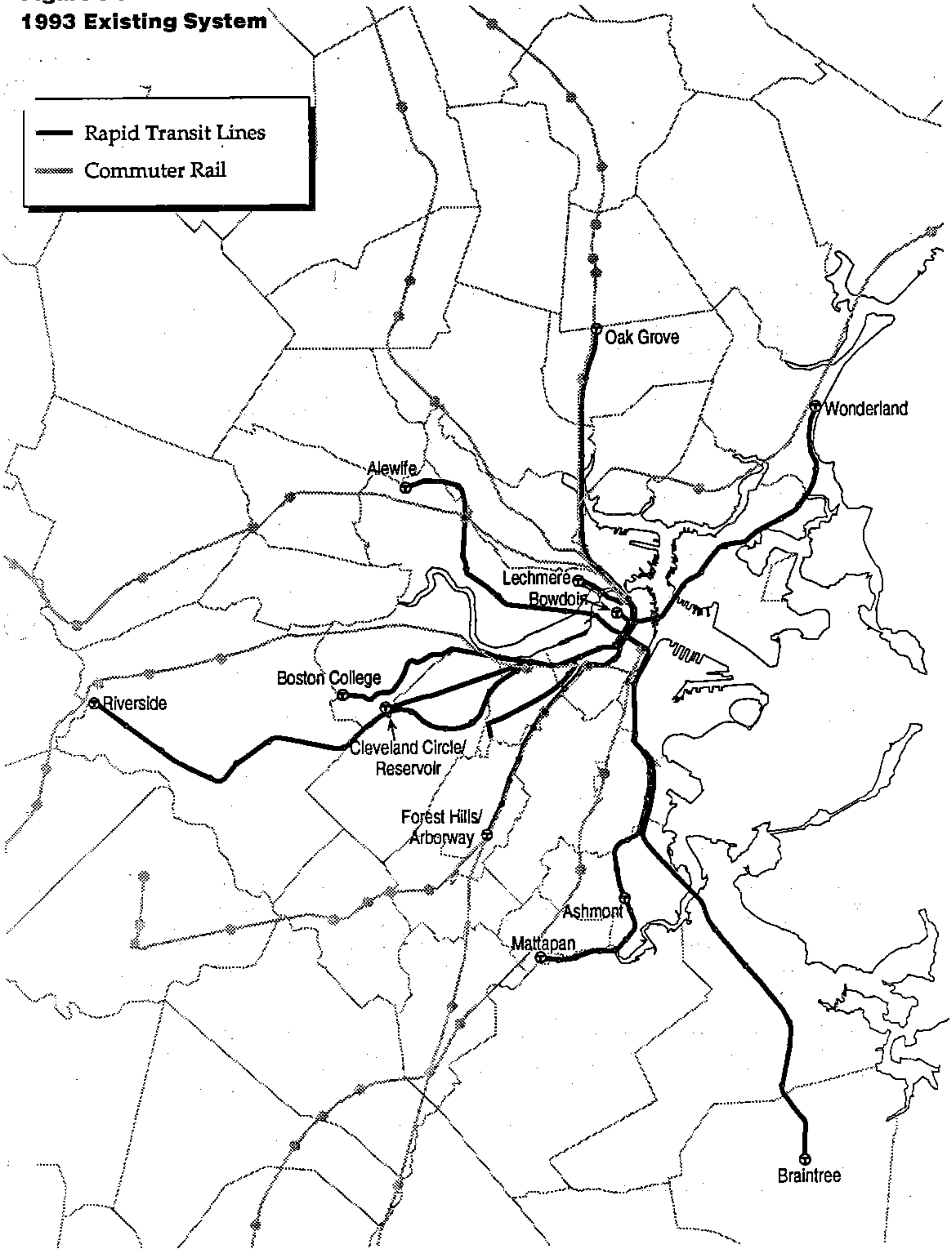
[1] The numerous bus and former streetcar lines will not be discussed, since they were not considered in detail in any of the major planning studies. Likewise, the planning of the commuter rail system will not be discussed, since it was privately owned and operated until the 1970s.

[2] Stat. 1894, Chapter 548.

Figure I-1
1993 Existing System



Street Subway from Shawmut Avenue to Scollay Square (now part of the Green Line)[3] and the East Boston Tunnel from Scollay Square to Maverick Square in East Boston (part of the Blue Line), but the fact that the statute laid out a large network with many branches makes it an important landmark in systems planning and the history of urban transit.

Subsequent Legislation

Several other acts of the legislature in the ensuing years altered the proposals made in the 1894 act, laying the foundations for the transit lines that were actually built. Chapter 534 of the acts of 1902 laid out plans for the Washington Street Tunnel (Orange Line from North Station to Chinatown), Chapter 520 of the acts of 1906 described the Cambridge subway (Red Line from Harvard to Park Street), and finally Chapter 741 of the acts of 1911 prepared the way for the Dorchester Tunnel from Park Street to Andrew (southern portion of the Red Line), the Boylston Street Subway from Kenmore to Tremont Street (Green Line) and a continuation of the East Boston Tunnel from Court Street to Bowdoin Square (western section of the Blue Line).

Report on Improved Transportation Facilities (1926)

The first major planning document to be produced after the core of the transit system was in place was the Report on Improved Transportation Facilities in the Boston Metropolitan District, published by the Division of Metropolitan Planning[4] in 1926. This report based its proposals upon a study of population trends in the Boston area, an analysis of ridership trends on the many steam railroad lines and on the streetcar and rapid transit system, and a survey of trouble spots in the existing system. The authors found that population was growing very quickly in the suburban areas immediately surrounding Boston, especially those to the west and south, such as Newton, Needham and Dedham, but that patronage of the steam railroads within five or six miles of the city was declining steeply. The railroads had lost their inner suburb commuter patronage to the streetcar and rapid transit facilities of the urban core in the early part of the century, and as the 1920's wore on, even more people were leaving the railroads to drive their own private automobiles. The automobile had not yet cut significantly into the patronage of the Boston Elevated, serving the urban core with an average of one million passengers per day, but if improvements were not made to the transit facilities, it was predicted that increasing numbers of people would desert the El because of the congestion and inconvenience. Improvements were especially necessary at the Park Street and Scollay Square stations which, because of the large number of trolley lines (eleven separate routes) which originated and terminated there, were subject to a severe congestion problem compounded by confusion and delays in loading and unloading passengers. The Planning Division recommended several changes to the system to alleviate this problem and also to provide more comprehensive service to the territory within five miles of the State House, which was seen as the proper domain of rapid transit.

Two projects received top priority: a through route between Maverick Square and Warren Street or Lake Street, Brighton which was essentially a connection between the East Boston Tunnel (Blue Line) and the Tremont Street and Boylston Street Subways (Green Line) emerging along Commonwealth Avenue; and a route from Lechmere to Huntington Avenue through the Tremont Street Subway, along the Albany and New Haven Railroad tracks and then along Huntington Avenue to a terminal at Tremont Street in Roxbury (see Figure I-2). These through routes operating in the Tremont Street subway would replace the eleven trolley routes and thereby greatly improve the congestion problems. Neither of these routes was ultimately instituted, although service along Huntington Avenue was eventually put into place with the opening of the Huntington Avenue Subway in 1941. As it turned out, several other proposals in the 1926 report, judged to be of lower priority, were actually carried out. These include:

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[3] Throughout this chapter, cross-references to the color scheme familiar to today's riders will be given in parentheses. The color scheme was instituted by the newly-formed MBTA in 1965.

[4] Part of the Metropolitan District Commission.

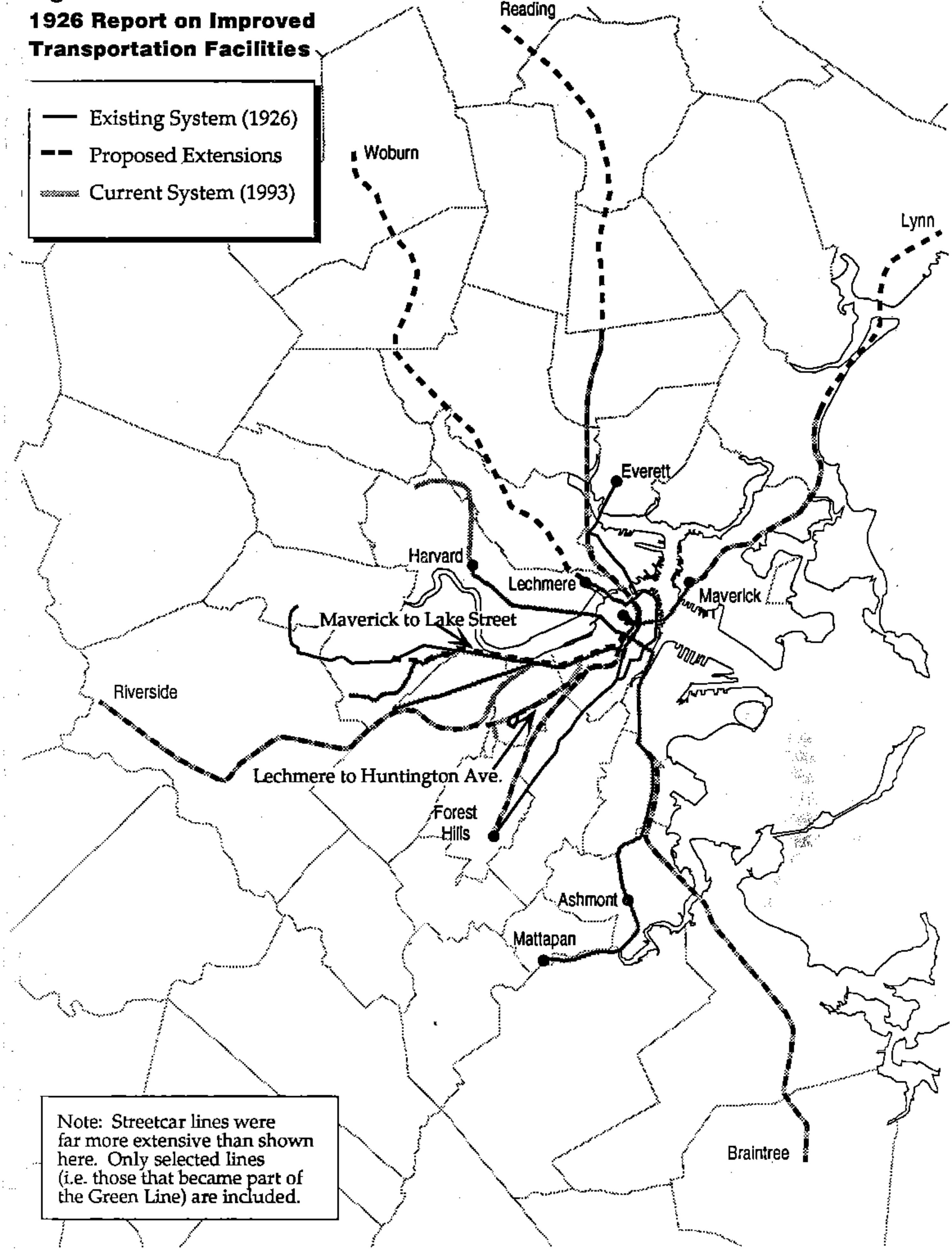
- Extension of East Boston route to Lynn via the Boston, Revere Beach and Lynn Narrow Gauge Railroad—completed as far as Revere in 1952
- Conversion of the Western Division of the Boston and Maine Railroad as far as Reading to a new rapid transit line—completed as far as Oak Grove in 1975-77
- Use of the Old Colony Railroad tracks for a transit extension to Braintree--completed in 1980
- New transit line parallel to Providence Division of the New Haven Railroad to Forest Hills—completed in 1987
- Extension of Huntington Avenue route through Brookline Village connecting to the Highland Branch of the Boston and Albany Railroad--use of the Highland Branch for the D Line through Kenmore instead completed in 1959 (Note: the connection from Brigham Circle to Brookline Village is still being studied).

There were also several other proposals which were subsequently dropped from consideration as well as two which have reappeared on the agenda:

- Extension from Lechmere to Woburn via Southern Division of the Boston and Maine Railroad—extension as far as Medford Hillside is currently being considered.
- Suggested study of a circumferential transit route as proposed by the City of Boston in 1923 (no particular alignment mentioned).

The second major function of this document was to suggest ways to solve the problem of the chronic deficits of the transit agencies. Since 1918, the Boston Elevated had been under public control but its financial problems had not ended. The report recommended the establishment of a corporation, owned by private stockholders, called the Metropolitan Transit System, which would assume the assets and liabilities of the El for a period of at least forty years. The directors of this corporation would be appointed by the governor and thus, although it would not be a state agency, control would be in the public domain. It was further recommended that the district for this new agency be expanded to twenty-nine cities and towns from the fourteen communities which had been bearing the deficits of the El under the Public Control Act of 1918. These suggestions were not followed until 1947 when the Metropolitan Transit Authority was created in response to the reports of the Coolidge Commission.

Figure I-2
1926 Report on Improved Transportation Facilities



Note: Streetcar lines were far more extensive than shown here. Only selected lines (i.e. those that became part of the Green Line) are included.

Coolidge Commission Reports (1945 - 1947)

In 1943, the legislature decided it was again time for an evaluation of the future shape of the rapid transit system and created the Metropolitan Transit Recess Commission headed by Senator Arthur W. Coolidge "for the purpose of making an investigation and study of the subject of rapid transit in the Boston metropolitan area."[5] The Coolidge Commission, as it came to be known, produced a report in April of 1945 and a second revised edition in 1947. As did the 1926 report, the Coolidge Commission report had two primary functions: to propose a layout for a transit system to fulfill the future needs of the Boston metropolitan area, and to recommend a reorganization of the transit agency to solve the perennial problem of the deficits of the Boston Elevated.

The Coolidge Commission considered population trends between 1900 and 1940 and concluded that the urban core areas were on the decline and that suburbs between five and ten miles from the State House were growing quickly. The Commission argued that the current demise of the public transportation system and the concurrent increase in automobile traffic congestion was a result of this population movement, since the existing rapid transit system only extended as far as five or six miles from the center of Boston. The report declares: "The obvious solution [to these problems] is the extension of rapid transit lines out to the areas where the population is growing, sufficiently extended to aid the development of the areas and to facilitate the movement of the population to and from the center of the City of Boston."

Specific proposals were based upon studies of the existing system and possible transit extensions using railroad rights-of-way. Commuter rail patronage for short-haul trips was declining, and it was assumed by the Coolidge Commission that rapid transit could take over the facilities at a minimal cost. Ridership estimates were based upon population trends and an assumed twelve percent ridership growth factor, derived from the El's experience with the transit extension to Ashmont in the late 1920s.

The projects listed in the 1947 Coolidge Commission report are a very ambitious list, effectively extending the rapid transit network out to ten to twelve miles in all directions (see Figure I-3):

- Northeast: an extension of the East Boston Line to Lynn
- North: an extension of the Elevated from Sullivan Square to Reading including a branch to Medford Square
- Northwest: an extension from Lechmere to Woburn and an extension of the Cambridge Subway from Harvard to West Cambridge (Alewife) and beyond to Lexington
- West: a second extension from West Cambridge to Waltham Highlands, an extension to Riverside from the Tremont Street Subway via the Main Line of the Boston and Albany Railroad, another extension to Riverside from Kenmore Square (forming a loop) via the Highland Branch of the Boston and Albany Railroad, and a branch off of the Highland Branch to Needham Junction and Bird's Hill
- Southwest: two possible extensions beyond Forest Hills to Readville and East Dedham, plus the possible realignment of the Elevated to the New Haven Railroad tracks from Essex Street to Forest Hills
- South: an extension to South Braintree from Savin Hill along the Old Colony Railroad right-of-way, and perhaps even further to Cohasset, Whitman and Brockton.

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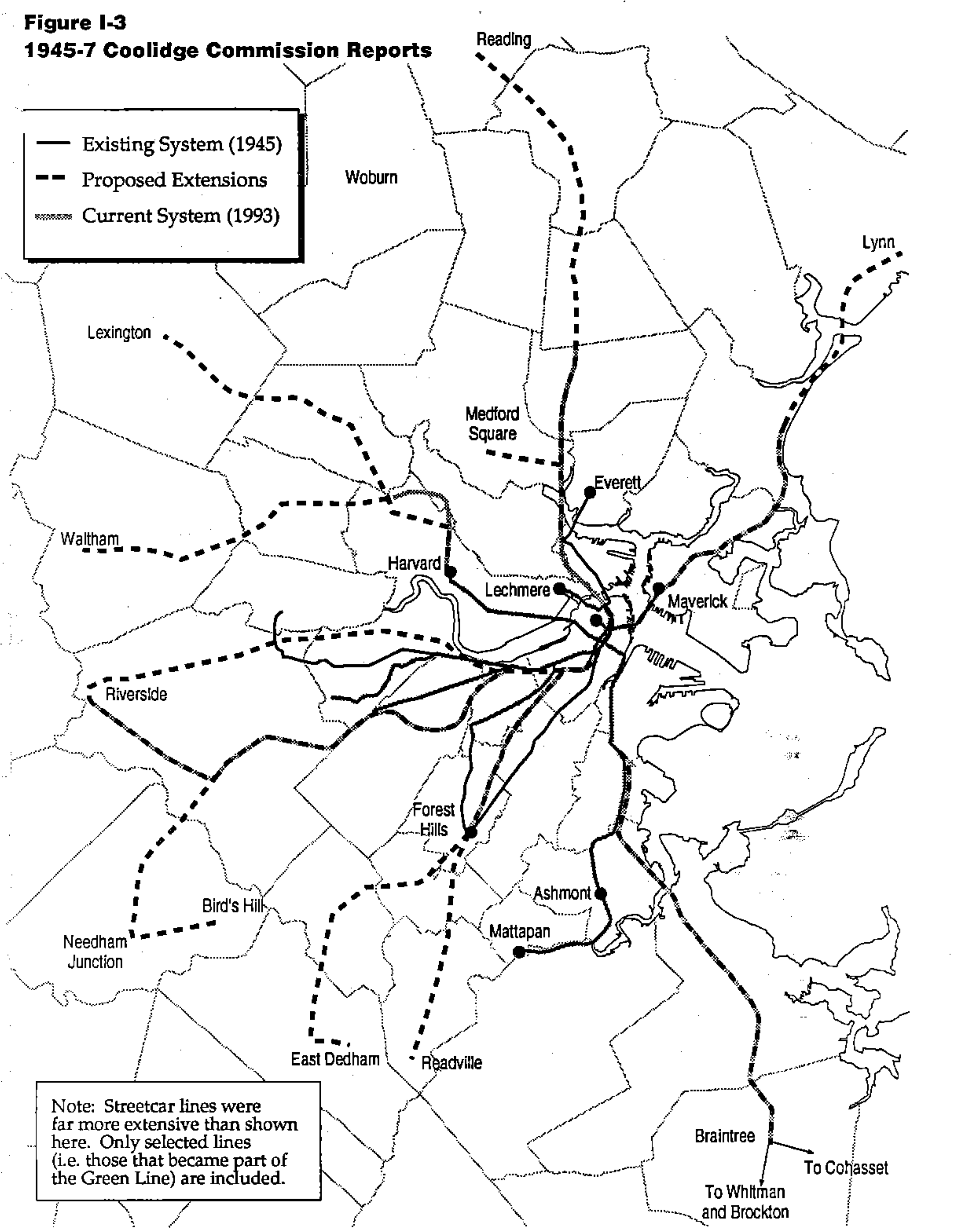
[5] Coolidge Commission Report 1945, p. 8

Figure I-3
1945-7 Coolidge Commission Reports



Note: Streetcar lines were far more extensive than shown here. Only selected lines (i.e. those that became part of the Green Line) are included.

The total predicted cost of this program, including some changes to the central subway between Boylston Street and Scollay Square came to $73,375,050. Of the many projects proposed in the Coolidge Commission report, five have been completed, all at a smaller scale than originally suggested:

1) Blue Line extended to Wonderland instead of Lynn in 1952,
2) Orange Line extended to Oak Grove instead of Reading in 1975-77,
3) Red Line extended to Alewife instead of Lexington and Waltham in 1985,
4) Orange Line relocated to Forest Hills in 1987 with no extensions beyond, and
5) Red Line extended to Braintree instead of South Braintree or the extensions beyond in 1980.

All of the cases where rapid transit lines were not extended were a result of the recommitment to Commuter Rail which began to take shape in the early 1970's.

As to the reorganization of the Boston Elevated, the Coolidge Commission recommended the establishment of a Metropolitan Transit Authority to assume the assets and liabilities of the El. As in the 1926 Report, it was suggested that the district for this Authority be expanded to twenty-nine cities and towns (all of those within a ten mile radius of the State House). The proposed legislation contained within the report formed the basis of the enabling legislation for the MTA, enacted in August of 1947.

1966 Program for Mass Transportation

Because of the comprehensive nature of the Coolidge Commission Reports and their far-reaching expansion plans, no further planning documents were produced during the existence of the Metropolitan Transit Authority. In the early 1960's, planning activities stirred again with the Boston Regional Planning Project and the Mass Transportation Demonstration Project. These studies were initiated due to the looming crisis caused by the continued decline of commuter rail and rapid transit and the resultant deficits of the rail companies and the MTA. The Boston Regional Study (1963) provided an in-depth analysis of land use and economic trends, a comprehensive description of the existing transportation systems including highway, public transportation and railroad, as well as an excellent historical overview of these transportation systems. The Demonstration Project (1964), carried out by the Mass Transportation Commission, was a series of experiments designed to determine how changes in the fare structure, fare levels, and service frequency affect patronage. Various tests were performed on commuter rail lines and bus lines (but not the rapid transit system, because the experiments would have been too difficult to perform) over a span of fifteen months, typically following this pattern: Stage 1 - reduce fares and increase service, Stage 2 - maintain higher level of service, restore fares to pre-test levels but institute a low off-peak fare, Stage 3 - make adjustments to service as necessary and continue stage 2 fares. The results of the experiments show that increased service is more important than lower fares in attracting new riders, but in almost all cases, not enough new riders would be attracted to pay for the increased service.

These planning studies provided much interesting information but they were also useful in that they helped to promote the formation of the Massachusetts Bay Transportation Authority. In July, 1964, the MBTA was established by the legislature under Chapter 161A of the General Laws of the Commonwealth. One of the stipulated responsibilities of the MBTA in section 18 was to "prepare and from time to time revise its program for mass transportation. The said program shall include a long-range plan for construction, reconstruction or alteration of facilities for mass transportation within the area constituting the authority."[6] The first such document to be produced was the Program for Mass Transportation of August, 1966. The MBTA was then in the process of reviewing its expansion plans in the context of the Eastern Massachusetts Regional Planning Project (EMRPP), and put forth in its own format the plans for public transportation facilities which were part of the EMRPP's comprehensive transportation planning effort.

The method used to evaluate proposed extensions was significantly more sophisticated than the simple population projections used in the 1926 and 1945 studies. The complexity was possible due to the major data gathering effort which had taken place in 1963 as part of the EMRPP. The home-based travel survey showed planners the numerous factors which go into a person's choice of mode and thus allowed them to develop formulas and models which would make reasonable estimations of ridership on new extensions.

The 1966 PMT contained an Action Plan consisting of several components with a total cost of $340 million. Five of the projects were extensions of rapid transit lines with the other components pertaining to rolling stock replacement, station modernization, and maintenance and storage facilities. Ideas for future expansion projects beyond the Action Plan were mentioned but not discussed in any detail.

Four of the five action projects have now been completed and, in fact, have been the focus of the MBTA's construction effort from 1966 to 1987. The Haymarket North extension on the Orange Line was completed by 1977 allowing for the demolition of the elevated structure through Charlestown and Everett. The second project was the Southwest Corridor. The 1966 PMT recommended the replacement of the Washington Street elevated structure with a new route along the New Haven Railroad tracks and an extension beyond Forest Hills to West Roxbury. The relocation of the Orange Line was completed in 1987, but the idea of extending beyond Forest Hills was dropped in favor of upgrading the Needham commuter rail line. The third project was the Harvard to Alewife extension of the Red Line which was completed in 1985, with the modification of a station at Davis Square in Somerville in addition to the original proposal of stations at Porter Square and Alewife. The Red Line was also to be extended in the other direction to the South Shore via the right-of-way of the former Old Colony Railroad. The PMT suggested extending as far south as Weymouth, but it was subsequently decided to stop at Braintree, which was accomplished by 1980. The final project, which has not been built to date, was a one-mile extension of the Green Line from Lechmere terminal into Somerville.

In addition to the projects, the PMT included a discussion of its relationship to private carriers in eastern Massachusetts. Continuation of commuter rail service by the railroad companies was in doubt at that point in time, reflected by the use of the railroad rights-of-way for the proposed transit extensions. The MBTA suggested in the PMT that commuter rail service could continue but in a reduced form, as more of a shuttle service from outlying areas to the ends of the rapid transit lines. The Orange Line at Malden, the Red Line at Alewife, and the Orange Line at Forest Hills and West Roxbury provided good opportunities for creating cross-platform links between railroad and rapid transit. As for buses, the MBTA recognized that changes would occur, with either the authority taking over routes from private companies, subsidizing those companies, or buying them out completely. The PMT made no firm plans for this but rather left the decisions up to the ongoing bus studies.

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[6] Chapter 563 of the Acts of 1964

EMRPP Recommended Highway and Transit Plan (1969)

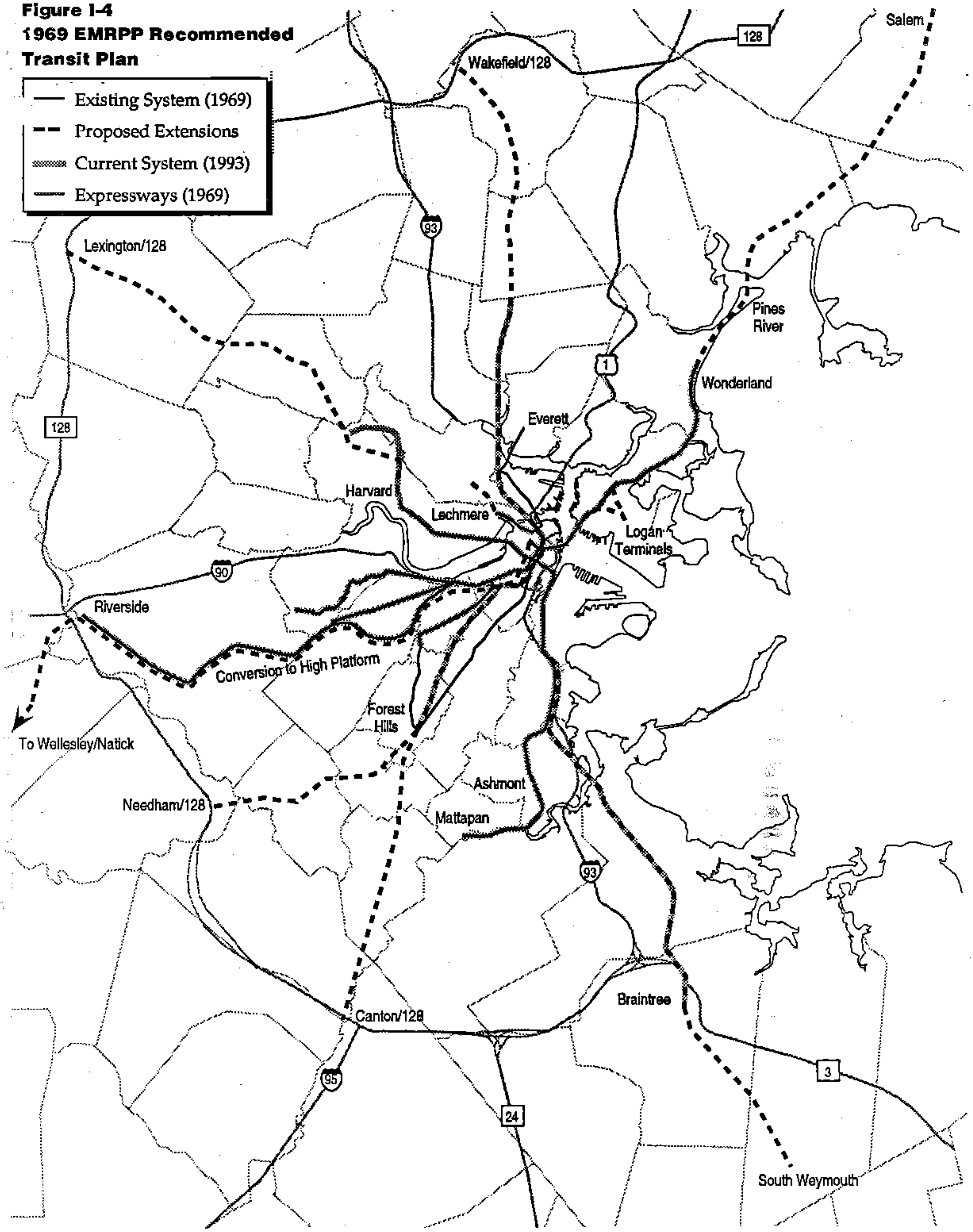
The final report of the EMRPP was published in January of 1969. The MBTA had participated in the project since its inception in 1964, although the project was done under the aegis of the Department of Public Works (now the Massachusetts Highway Department), specifically the DPW's Bureau of Transportation Planning and Development. While the MBTA had been quite restrained in the 1966 PMT in terms of the ambitiousness of its expansion plans, the Recommended Highway and Transit Plan allowed it to indulge in some longer range speculation. The plan is divided into three elements: Committed Projects, the Short-range Program (1968-1975) and the Long-range Program (1975-1990). The list of committed projects corresponds to the list in the 1966 PMT, but the Short-range projects include a proposal to extend the Blue Line from Wonderland to Pines River and the Orange Line from West Roxbury to Route 128 in Needham and from Forest Hills to Route 128 in Canton. The Long-range program includes a further extension of the Blue Line to Salem and a new branch of the Blue Line to the terminals at Logan Airport, the Orange Line north to Route 128 in Wakefield, the Red line from Alewife to Route 128 in Lexington, and several changes to the Riverside line including a connection to the Blue Line in the downtown area, a conversion of the existing line to high-platform rapid transit and an extension of the line out to the Wellesley-Natick border. (See Figure I-4).

These proposals all follow the pattern of extending the rapid transit lines out to terminals along Route 128. The fact that such plans appear in the EMRPP report but not in the PMT is attributable to the overall theme of the report deriving from the highway plans: to create a complete network of transportation facilities, both expressway and rapid transit, connecting Route 128 and the urban core as a set of spokes between the rim of the Boston area and its hub. This theme is the defining characteristic of the EMRPP, even though the transit projects recommended within it go back a long way, most to 1945 and some to 1926.

Final Report of the Boston Transportation Planning Review (1972)

The Boston Transportation Planning Review (BTPR) was a major restudy of the plans laid out in the EMRPP report. The restudy took place in 1971-72 and marked a fundamental shift in transportation priorities in the Boston region from highways to public transportation. The effect of the BTPR on transit plans was not so much to inflate them, but rather to move them to the top of the construction agenda replacing the urban expressways which had been discarded. The plans themselves, in fact, deflated a bit to return to the scale of the 1966 PMT. No extensions of the Blue Line were planned in the BTPR with instead a minor upgrading to improve roadway access to Blue Line stations. The Orange Line would not be stretched north beyond Malden, although the extensions south beyond Forest Hills to Needham and Canton were retained. The Red Line extension to Alewife was altered to include the Davis Square station, and the possibility of extending to Arlington Heights was not ruled out. The South Shore Red Line extension was planned to go only as far as South Quincy. The extension of the Green Line from Lechmere to Somerville was retained for further study, but it was of low priority. There was discussion of replacement service for the Washington Street corridor in the South End and Roxbury which would lose its rapid transit service with the demolition of the elevated structure and relocation of the Orange Line. No firm plans were made as to the exact nature of the replacement service. Finally, there was much enthusiasm for the idea of a Circumferential Transit line (although no particular alignment was laid out), an idea originating in 1923, but which had been absent from the discussion for a long time. One other non-rapid-transit element was included in the BTPR

Figure 1-4
1969 EMRPP Recommended Transit Plan



program: a third harbor crossing reserved for buses, taxis, airport limousines, trucks and emergency vehicles. Such a special-use tunnel would encourage the use of multiple-occupancy vehicles for access to Logan Airport.

Transportation Plan (1974-1983) / Ten Year Transit Development Program (1974-1983)

New laws were enacted at the federal level during the early 1970s concerning transportation planning in metropolitan areas. Specifically, federal regulations required the formation of a Metropolitan Planning Organization to carry out continuing, comprehensive and cooperative planning, the "Three-C" process. As part of this process, the MPO was required to produce a set of documents, one of which was the Transportation Plan. The first Plan to be written under these new guidelines was released in July 1974. The preparation of this document was undertaken by a group comprised of technical staff from four agencies: the Executive Office of Transportation and Construction, the Metropolitan Area Planning Council, the Massachusetts Department of Public Works and the Massachusetts Bay Transportation Authority.

At approximately the same time, the MBTA published the Ten Year Transit Development Program 1974-1983. Although this document was not called a Program for Mass Transportation, it was effectively a revision of the 1966 PMT which had been amended in 1968, 1969 and 1971. The Development Program and the Transportation Plan were the first planning documents to be produced after the BTPR, and they clearly show the influence of the restudy and the conclusions of its Final Report. In terms of the projects included in these reports, though, there is an equally strong influence of the transit element of the Recommended Highway and Transit Plan of the EMRPP.

One other important event occurring at this time was the purchase by the MBTA of the railroad rights-of-way and equipment of the Penn Central and the Boston and Maine Railroads. The fate of the railroad companies had been in doubt for a long time, but the institution of the Commuter Rail Improvement Program in 1972 gave the MBTA the task of taking over and revitalizing the commuter rail system. In 1974, the transfer of property from the private companies to the MBTA was in progress, and the MBTA was in the process of forming a Commuter Rail Directorate in its organizational structure. These two documents reflect the changed status of commuter rail by including, for the first time, improvement projects for the railroad lines and equipment.

For the purpose of organizing the proposals, the metropolitan area was divided into corridors. In the urban core area, there were two main proposals contained in both documents: a connection between the Blue Line and the Green Line via a new tunnel under Beacon Hill and the Boston Common linking Bowdoin station to the subway under Boylston Street, and a circumferential transit line running around the downtown area from South Station to Sullivan Square in Charlestown. In addition, the Transportation Plan listed other possible improvements including a rail connection between North Station and South Station and the restoration and revitalization of South Station.

In the north shore corridor, two improvements were planned: an extension of the Blue Line from its terminal at Wonderland to Lynn, Salem, or even as far north as Route 128 in Peabody, and an upgrade of the commuter rail lines to Rockport and Ipswich. The northern corridor similarly has two improvements: an extension of the Orange Line from Oak Grove to Route 128, Reading Center or Route I-93 at the Reading-Wilmington line, and upgrade of commuter rail service on the New Hampshire Division through Woburn and Wilmington. The Orange Line extension would replace commuter rail service from Reading to North Station, but freight service would be retained on a third track.

Two transit improvements were planned for the northwest corridor: the Red Line would be extended from Harvard through Porter Square and Davis Square in Somerville to Alewife and perhaps beyond to Arlington Center, Arlington Heights or Route 128 in Lexington, and the Green Line would be extended 1.1 miles from the Lechmere terminal to Washington Street in Somerville. This second project was relegated to a low priority status when the Red Line extension was altered during the BTPR to include the station in Davis Square. Commuter rail service would also be improved on the Fitchburg Division commuter rail line including a transfer facility between the rail line and the new Red Line extension either at Alewife or at Porter Square.

There was only one listed improvement in the western corridor, the reconstruction and upgrade of the tracks and facilities for the Green Line Riverside branch and the Boston and Albany Main Line commuter rail route from Newton to Westborough. The southwest corridor, on the other hand, had a number of large scale projects. The largest of them was the relocation of the Orange Line from the elevated structure on Washington Street to the Penn Central (New Haven Railroad) right-of-way to Forest Hills. This project included a new tunnel in the South Cove area from the Washington Street Tunnel to the Boston and Albany right-of-way (under construction at the time of publication of these documents), and the removal of the railroad embankment along the Penn Central right-of-way. In addition to the relocation project, the Orange Line was to be extended to West Roxbury and Needham, replacing the existing commuter rail service on those tracks. To replace the service of the elevated line on Washington Street in the South End and Roxbury, it was planned to reactivate the Green Line tunnel under Tremont Street south of Boylston for a new light rail extension to Roxbury, or to institute bus service including reserved lanes. One other project concerning the Green Line was the connection from Brigham Circle to Brookline Village, linking the E and D lines. In addition to these transit projects, upgrades for all of the commuter rail lines in this corridor were planned.

The final corridor was the South Shore which had one main project: the completion of the Red Line extension to South Braintree. The extension had been built as far as Quincy Center in 1971 and the remaining segment, including two new stations was under construction at the time. Further extensions to Brockton, South Weymouth or Hingham were retained for consideration.

1978 Program for Mass Transportation

Between the 1966 edition of the PMT and the next version to come out in 1978, the legislature passed a law in 1973[7] amending Chapter 161A so as to transfer the responsibility for producing the PMT from the MBTA to the Executive Office of Transportation and Construction, which had been formed in the restructuring of government in 1971. EOTC undertook the revision of the PMT in late 1975, beginning a three-year process which ended with the approval of the Revised PMT by the Advisory Board to the MBTA in December of 1978. A great deal of analysis went into the production of this document in terms of studying the plans of the early seventies and using complex forecasting models to determine the costs and benefits of the various proposals. Improved forecasting methods allowed planners to have a better idea of future population and employment trends as well as likely ridership levels.

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[7] Chapter 1140 §7 of the Acts of 1973

As a preliminary step to laying out the construction program for public transportation facilities, the PMT includes an extensive discussion of policy objectives. Six major headings furnish the framework for the policy of the MBTA:

1) Management - to manage the system efficiently so as to provide a high level of service at the minimum cost to the rider and the taxpayer;
2) Ridership - to promote increased patronage of the mass transit system;
3) Environment - to provide services which are beneficial to the environment from the standpoint of energy efficiency, decreased pollution, and minimized negative impacts on areas near transportation facilities;
4) Economic and Physical Development - to create economic activity through construction projects and to promote the development of urban areas in the region;
5) Transportation Service - to make the transit system as fast, convenient, attractive and safe as possible; and,
6) Services for Elderly and Handicapped - to increase the accessibility of the transit system and provide paratransit service where needed.

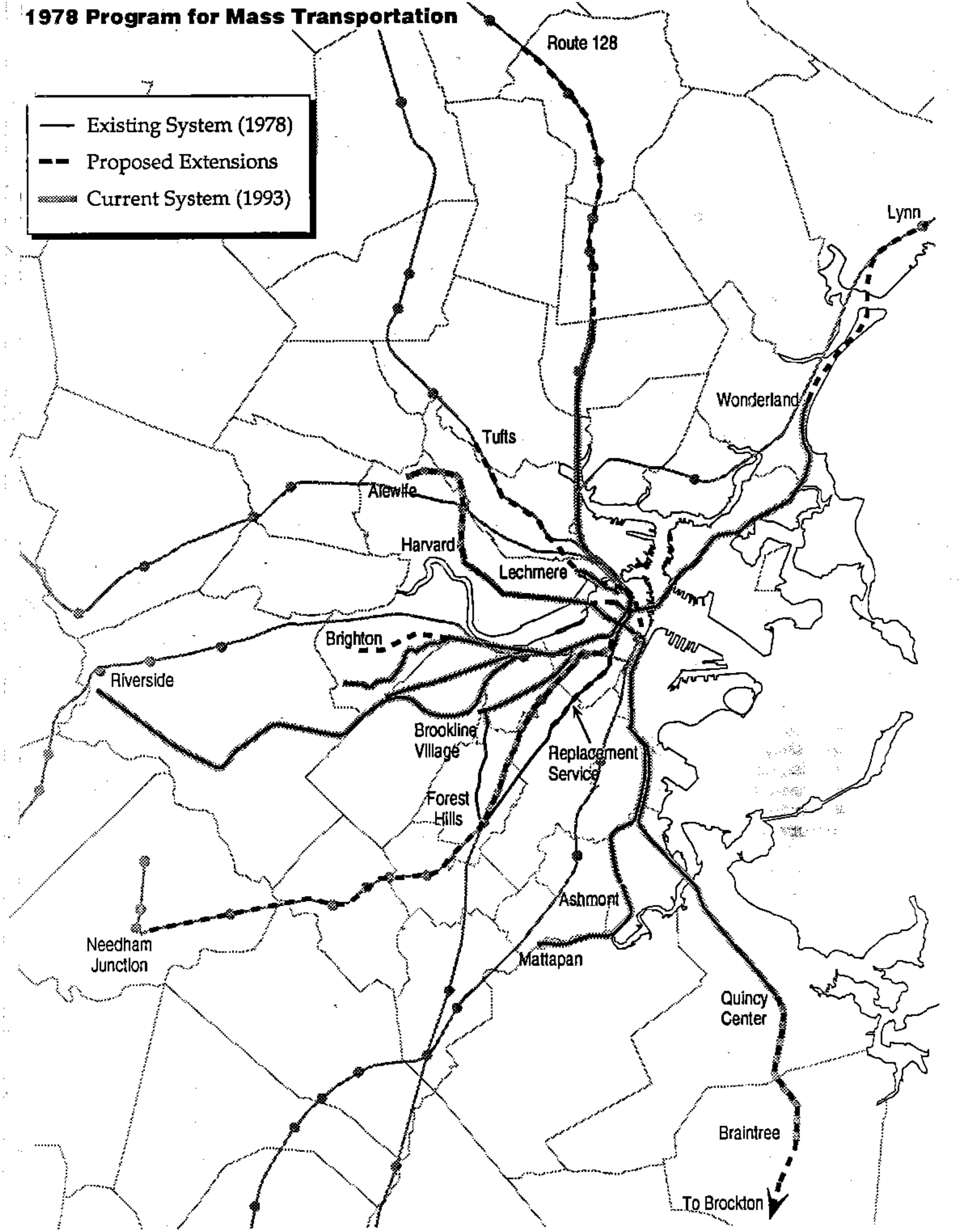
These overarching goals serve as the fundamental rationale for the proposed improvements.

The program consisted of two segments, one for plant and vehicle improvements and the other for service expansion. The first section covered such items as electric power sources for the system, track renovations, improvements in the signaling system and communications, maintenance and storage facilities, bus and rapid transit vehicles, station modernization, parking capacity expansion, and accessibility improvement projects.

The chapter on new service projects listed fifteen proposals, including improvements to all of the transit lines and three new routes. The projects are listed in counterclockwise order, according to corridor (see Figure I-5):

- Blue Line extension from Wonderland to Lynn
- Orange Line extension from Oak Grove to Route 128
- Green Line extension from Lechmere to Tufts
- Red Line extension from Harvard to Alewife
- Green Line extension to Brighton (partial rehabilitation of the A Line)
- Brookline Village Connector - connection between the Riverside Line (D) and the Arborway Line (E)
- Orange Line relocation in the southwest corridor
- West Roxbury/Needham Service - either extension of the Orange Line from Forest Hills or major commuter rail upgrade
- Roxbury/South End Replacement Service
- Rail service to Brockton - extension of Red Line, commuter rail line to Boston, railroad shuttle to Braintree, or a special lightweight diesel rail car joining the Red Line tracks in Quincy
- Commuter Boats for the South Shore
- Bowdoin-Charles Connector - connection between the Blue Line and the Red Line at Charles Station
- North Station Green Line Relocation - removal of the elevated structure over Causeway Street and reconstruct the Green Line station
- North Station-South Station connector - a new rail link as part of the Central Artery project
- Circumferential Transit - a new transit line around the fringe of the Downtown Boston

Figure I-5
1978 Program for Mass Transportation



Of these fifteen projects, four have been implemented: the Harvard-Alewife extension was completed in 1985, the Orange Line relocation was finished in 1987, the upgrade of commuter rail service to West Roxbury and Needham opened at the same time as the new Orange Line, and commuter boat service to Hingham has been running since 1984 with subsidies from the MBTA. The Old Colony Railroad Rehabilitation is now underway, the North Station Green Line relocation is planned to be implemented as the new North Station and Boston Garden are built. The Roxbury/South End replacement service, and the Bowdoin-Charles connector are in the planning stages. The rest of the projects are being retained, pending a revision of the PMT.

Following the listing of projects, the 1978 PMT had three more chapters. A section on low-cost capital improvements discussed various transportation systems management (TSM) programs such as marketing, maintenance and the promotion of carpooling, bicycling and pedestrian travel. Accessibility issues for senior citizens and people with disabilities were also discussed. A chapter outlining the financing procedures for the capital improvements was followed by a summary of the goals and impacts of the program, highlighting the benefits of transit investment and some of the land use and development changes that would occur as a result of the implementation of the program.

1982 / 3 Transportation Plan

The most recent version of the Transportation Plan for the Boston Region preceding the current update is the Fiscal Year 1983 edition. Like the 1974 Plan, this document encompasses the entire transportation system and discusses policy objectives for transportation and regional development. The projects in the Plan are divided into four categories depending on the degree of change to the physical plant involved in the project. The largest degree change is plant expansion, "any development and construction or acquisition of facilities or equipment for the purpose of increasing physical capacity."[8] Lesser degrees of change are denoted as plant replacement, plant renovation and plant enhancement. The projects listed in these four categories correspond to the projects in the 1978 PMT: twelve of the fifteen expansion projects in the PMT are included under plant expansion, the other three are listed under plant replacement (the Orange Line relocation, the Roxbury replacement service, and the Green Line/North Station relocation), and the other improvements in the PMT such as storage and maintenance facilities and other system upgrades are distributed under plant replacement, renovation and enhancement.

Conclusion

Both the Transportation Plan and the Program for Mass Transportation are now being updated, and they will both contain some system expansion projects for the MBTA. It is likely that almost all of the recommended projects can be found in at least one of the historical planning studies. In most cases, it is clear how the system could be expanded; the route of expansion has not changed markedly over time.

However, planning efforts for mass transit have changed character over the years, as the relationship of mass transit to the other modes of travel has been transformed. In the early part of the century, mass transit competed directly with commuter rail services, while the automobile was not seen as an immediate threat. In the middle part of the century, rapid transit came to be seen as a replacement for commuter rail, at least within a ten mile radius of downtown Boston. The automobile, meanwhile, was eating away at the market share of both commuter rail and transit. In the 1970s, rapid transit became a complement to a revitalized commuter rail system, while both were severely threatened by the dominance of the automobile. In the late '80s and '90s, intermodalism has come of age, and it is clearly recognized that mass transit is an indispensable complement to the regional highway system. To facilitate the connection between autos and transit, there has been a great emphasis on constructing parking lots at transit stations, and in some cases, locating new transit stations at the intersections of rail lines and major highways.

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[8] Transportation Plan FY 1983, p. 49

Changes in land use patterns have also affected mass transit planning. As population began to disperse in the middle part of the century, it was thought that the transit system should reach out into the suburbs to follow. In the 1970s, the region realized that commuter rail could serve suburbs more efficiently than rapid transit lines, and so some of the longer rapid transit extensions have not been pursued. Since the BTPR, there has been a strong policy commitment to support development and commerce in the urban core. As a result, many transportation investments have focused on the downtown area.

Mass transit facilities have a very long life span. The initial investment is very high, but the benefits extend for many decades. Although Boston is a mature metropolitan area relative to others in North America, it is still growing and developing. The transit system functions well, but it is not complete. Planners throughout the 20th Century have seen how to expand it, and planners in the 21st Century will likely follow the same paths.